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CHEMICAL LECTURES,

Publickly Read at LONDON,
In the Years 1731, and 1732;
And at SCARBOROUGH, in 1733;
For the IMPROVEMENT of
ARTS, TRADES,
AND
NATURAL PHILOSOPHY.

By *PETER SHAW*, M.D. F.R.S.
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MDCCLV.

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TO THE

Right Honourable the

Lord Viſcount *Lonſdale*,

Lord PRIVY-SEAL, &c.

MY LORD,

AS your Lordſhip was pleaſed to honour theſe Lectures with your Notice in Manuſcript, I take the Liberty of laying them before you in Print; being deſirous the Publick ſhould know, that their Deſign was approved of by ſo unexceptionable a Judge.

For, beſides your uncommon Skill in Civil Policy, the Laws, and all the Branches of Publick Buſineſs; you have, like the Illuſtrious Lord *Bacon*, a Talent for the Improvement of Arts, and a Pleaſure, and Sagacity, in purſuing natural Enquiries.

Were I not, therefore, ſenſible, my Lord, that your Candour is as extenſive as your Learning, I ſhould be cautious of thus ſubmitting theſe ſlender Enquiries to your View; as they are neither conducted in a Manner ſuitable to your correct and exquiſite Taſte; nor purſued to ſuch a Length, as your great Knowledge in Philoſophical Matters may juſtly require.

But this gives me farther Encouragement, that I do not know a more uſeful

ful Subject, than the preſent, to a Trading Nation; nor a Perſon better qualified than your Lordſhip, to perceive its Tendency, and direct its Improvement.

I am

MY LORD,

YOUR LORDSHIP'S

Moſt obliged, and devoted humble Servant,

PETER SHAW.

Scarborough,
July 15. 1733.

ADVERTISEMENT.

THE following Lectures had the Honour to be read before a noble Audience, who candidly overlooked their Failings, and requeſted their Publication.

As the Deſign is of large Extent, little more than a Sample of the whole could at preſent be given; the farther Improvement of it being left to others.

The Experiments here employed, tho' many of them new, are generally ſimple; or performable with little Coſt, and Apparatus: But if a few particular Inſtruments, and Trials, hereafter intimated, were to be made, and properly uſed, much greater Diſcoveries might be reaſonably expected.

A GLOSSARY: OR Explanation of the TECHNICAL TERMS in this Work.

ACid. By *Acids* are meant all thoſe Things that taſte ſour; as Vinegar, Tartar, Juice of Crabs, Lemons, *&c.* Spirit of Nitre, Spirit of Salt, *&c.* and which, when mixed with a due Proportion of an *Alkali*, conſtitute a neutral Body, wherein neither *Acid* nor *Alkali* prevails; whence it alters not the Colour of Syrup of Violets. *See* Alkali *and* Neutrals.

Adits. *See* Burrows.

Alcohol. Is pure and perfect Spirit of Wine, without the leaſt Particle of Water, or Phlegm.

Alkali. Is a Word of extenſive Signification, and chemically denotes a large Tribe of Bodies. For all Bodies may be chemically conſidered under three Tribes; or as being either *Alkalies*, *Acids*, or *Neutrals*. *Alkalies* have this eſſential Property, that when mixed, or united, with *Acids*, they conſtitute *Neutrals*. But a more common Mark of an *Alkali* is, that it turns Syrup of Violets green, as an *Acid* turns it red; whilſt the Admixture of a *Neutral* Body does not alter the Colour of that Syrup. Thus Pot-Aſh, Salt of Tartar, and all fixed vegetable Salts; as likewiſe all volatile animal Salts and Spirits, are artificial *Alkalies*; as Chalk, the teſtaceous Bodies, *&c.* are natural *Alkalies.* And thus, in the vegetable Kingdom, Onions, Leeks, Garlick, Muſtard, *&c.* are *Alkaline*; as Sorrel, Wood-Sorrel, the Juice of Lemons, Oranges, Verjuice, *&c.* are *Acid.* Their Difference alſo is manifeſt from the Taſte, when the Habit of thus diſtinguiſhing them is acquired. *See* Acids *and* Neutrals.

Amalgamation. Is the Diſſolution, or Mixture of any Metal with Quickſilver: But Iron, of all the Metals, will not amalgamate, or unite therewith.

Aſſaying. Is the Art of diſcovering how much pure Metal is contained in any Ore, or Coin, aſſigned. Hence *to make an Eſſay*, is to produce a Lump, or Grain, of pure Metal, from any ſmall Quantity of Ore, or Coin.

Axioms. By *Axioms* are meant a Kind of Corollaries, Conſequences, or Reſults, of certain Experiments, Facts, Obſervations, or particular Doctrines; ſo as to recapitulate a certain uſeful Truth, contained in the preceding Part of the Work, and ſet it in a clearer Light, with regard to Theory, or Speculation; As Canons, or Rules, regard Experience or Practice. *See* Canons.

Balneum Mariæ. Or Water-Heat, is no more than a Veſſel of Water, ſet in a Furnace, or over the Fire, with another Veſſel put into the Water; which latter Veſſel contains the Matter, or Subject, of the Operation.

Buddling Diſhes. Are ſhallow Diſhes, like the Baſons of a Pair of Scales, for the waſhing of Ores by the Hand.

Burrows. In Mining, are the Paſſages leading into a Mine, and cut thro' the Sides of a Hill, or Mountain, ſo large that the Workmen may conveniently wheel out the Ore in Barrows, or carry it along in Baſkets.

Calcination. Is the burning of a Body in an open Fire, in order to diſcharge its more volatile Parts, or reduce it to Powder.

Canons. Are Rules of Practice, or Directions, for producing Effects, or performing Operations; and have the ſame Regard to Practice, as Axioms have to Theory. *See* Axioms.

Caput Mortuum. Is that Part of the Matter, which remains behind after Diſtillation, or Sublimation.

Cementation. Is the cloſe burning of a hard or metalline Body, with certain opening Powders, ſtrew'd betwixt its groſſer Parts; ſo as to ſoften, tinge, or impregnate them, with the Fumes of ſuch Powders; or it is the Introduction of any Mineral, or Metallic Fumes into the ſolid Plates of a Metal, by Means of a proper Heat, applied to a cloſe Veſſel, or double Crucible, wherein the Plates are laid, with the pulverized Matter ſtrew'd between them.

Clarification. *See* Depuration.

Concentrating. Is bringing the required Parts of a Subject cloſer together; as Salt-Water is concentrated by evaporating the aqueous Humidity; and Wine by freezing out, or ſeparating its Water, in the Form of Ice.

Copelling, or *Cupelling.* Is putting metallic Matters upon a cover'd Veſſel of Bone-Aſhes in a naked Fire, to try what Gold or Silver they will afford.

Cryſtallization. Is the Operation, whereby Salts diſſolved in Water ſhoot into Glebes, of particular Figures, according to the Nature of each Salt.

Decantation. Is the pouring off a clearer Liquor from a groſſer Sediment, after ſtanding.

Deflagration. Is ſetting exploſive Matters on Fire in a Crucible, or other Veſſel, and ſuffering them to burn out; as when Nitre, or Tartar, are thrown into a red-hot Crucible, or to any melted Matter, whilſt it continues in the Fire.

Depuration. Is the making of any Matter pure, or freeing it from the Droſs, Dirt, or other heterogeneous Parts, wherewith it may happen to be mixed: So Honey is depurated, or clarified, by heating it, and taking off the Scum that riſes to the Top.

Digeſtion. Is ſuffering ſolid and liquid, or groſſer and finer Matters, to ſtand together in a gentle Heat for ſome Time, that the Liquor may extract the Virtues of the ſolid Ingredients; or the whole become more ſubtile and uniform.

Diſtillation. Is the raiſing of Liquids into Vapour by Heat; and condenſing that Vapour into a Liquid again.

Elæoſaccharum. Is an intimate Mixture of any eſſential Oil, with Sugar; by grinding them together in a Mortar.

Elements. *See* Principles.

Elixation. Is the waſhing a Matter with Water, in order to get out what will diſſolve therein.

Empyreuma. Is a nauſeous Taſte, or Odour, proceeding from the Subject being ſcorched, or over-heated, in the Operation; as when Milk is burnt to, as they call it.

Eſſential, or *Chemical Oils.* Are the native Oils of Vegetables, drawn from them by Diſtillation with Water.

Evaporation. Is the ſetting a Liquor in a gentle Heat, to diſcharge its ſuperfluous Humidity, or obtain its dry Remainder.

Faints. Are the Liquor that runs from the Still, upon diſtilling any inflammable Spirit, after all the Proof-Spirit is come over. *See* Proof.

Filtration. Is ſuffering any Liquor to paſs thro' Cap-Paper, or rather a peculiar Kind of filtring Paper, into a clean Veſſel, or Glaſs; the Paper being cut conically for the Purpoſe, and put into a Glaſs Funnel, or laid upon a Stone Colander, or Strainer.

Form. Is the particular Act, or Law of Nature, whereby a Thing is produced.

Flux. Is any Matter added to an Ore, or metallic Matter, in order to make it melt, or run the eaſier, and yield a greater Quantity, or a purer Metal.

Fulmination. Is the ſame as *Deflagration*, which ſee.

Fuſing. Is the ſame as Melting, being a Term generally applied to the melting of Metals, and metallic Matters, with a ſtrong Heat.

Inſolation. Is ſuffering Matters to ſtand and digeſt in the Heat of the Sun, inſtead of uſing the Heat of a Furnace.

Lac, or *Laque.* Is a Kind of Extract, or thick Body of Colour, prepared chiefly from vegetable Subjects, for Painters Uſe. Of theſe *Laques* there are ſeveral Sorts; but in a more particular Senſe, it ſignifies the *Red Laque* obtained by boiling *Stick-Lac* in Water.

Lavaderos. In Mining, are the Houſes, or large Troughs, where the Ore is waſhed.

Limation. Is the filing of a Metal, or metallic Subſtance, ſo as to reduce it into ſmall Parts, called the Filings of that Metal.

Lixivium. Is the ſame Thing as Lee, or a Solution of Salts, by boiling any ſaline Matter in Water.

Load. In Mining, is the ſame as Ore.

Lotion. Is the waſhing of a Body in Water, to get out its Salt, or whatever elſe will diſſolve in Water.

Low-Wines. Are a weak Spirit, or the firſt Runnings of the Still, in diſtilling Brandies or Spirits, from Waſh or Wines, and mixed along with the ſecond Running, or more watry Part.

Menſtruum. Is any Body applied to another, ſo as to diſſolve it, and intimately mix its Parts with the Parts of the other: in which Reſpect the former may be called the *Solvent*, and the latter the *Solvend.*

Mercury. Is another Name for *Quickſilver.*

Metallurgy. Includes the whole Art of working Metals from the Ore to ſaleable Metal.

Muffle. Is an arched earthen Inſtrument made to cover a Teſt, in Cupelling, ſo as that the Coals, or Aſhes of the Fire, may not fall in upon the Subject. *See* Cupelling.

Muſt. Is the unfermented Juice of the Grape; or any other liquid fermentable Subſtance, before it enters the Act of Fermentation. *See* Stum.

Neutrals, or *Neutral Bodies.* Are ſuch Bodies as manifeſt no Signs of either *Alkali*, or *Acid*, upon any of the Trials known, and allowed to diſcover them; as particularly not by the Taſte, or the Admixture of Syrup of Violets, *&c.* *See* Acid *and* Alkali.

Per Deliquium. Is the running of diſſolvable Things into Liquor, by barely expoſing them to the open Air, or to the moiſt Air of a Cellar.

Phlegm. Is the ſame as Water, or aqueous Liquor.

Precipitation. Is the depoſiting of a Sediment; either by a Liquor ſtanding at Reſt, or when any Addition is uſed for the Purpoſe.

Principles. Are the different ſimple Matters, whereof a Body is compoſed.

Proof. In Spirits is meant of a certain Trial, or Way of examining their Strength, by the Bubbles that ariſe on their Surface upon ſhaking them in a Phial.

Quartation. Is the Separating of Gold from Silver, by Means of *Aqua-Fortis* or *Aqua-Regia.*

Quinteſſence Is the Mixture of an eſſential Oil with *Alcohol.*

Rectification. Is purifying a Subject, by repeating the Operations; as Brandy is purified, or ſeparated, from its Phlegm, by repeated Diſtillation.

Reduction. Is the *reducing*, or recovering a Metal from its *Calx*, or *Aſhes*; and may likewiſe be applied, when any Body deſtroyed, as to its natural Form, or Appearance, is made to aſſume that Form again.

Refrigeratory. Is a Veſſel of cold Water, thro' which a winding metalline Pipe takes its Courſe, from the Hot Still, ſo as to bring off the Liquor cool, by Diſtillation.

Regulus. Is an impure, or imperfect metallic Subſtance, that falls to the Bottom of the Crucible in the melting of Ores, or impure metallic Subſtances.

Scoria. *See* Slag

Separating-Glaſs. Is a bellied Glaſs, open at top, and ending in a hollow Stem below; ſo that a Mixture of Oil and Water being put therein, and ſuffered to reſt till they ſeparate, the Water may be poured off from the Oil.

Slag. Is the Droſs, Cruſt, or *Scoria*, found at the Top of a melted Metal, or metallic Matter; being often in the Form of a vitrified Maſs or Glaſſy Subſtance, and proceeding from the Flux employed, and united with ſome ſtony recrementitious Matter contained in the Ore. But when a large Proportion of a ſaline Flux is uſed, the Slag will relent, or even diſſolve in the Air.

Solvent. *See* Menſtruum.

Stum. Is *Muſt*, clarified by ſtanding and racking, then put up into matched Caſks, that is, Caſks impregnated with the Fume of burning Brimſtone, ſo as to be preſerved ſound in an unfermented State. *See* Muſt.

Sublimation. Is the raiſing of a dry Body by Heat into Flowers, or a ſolid Cake, at the Top of the containing Veſſel; being a Kind of Diſtillation ſuited to dry Bodies.

Subſidence. Is the ſuffering a Liquor to ſettle, and fine itſelf, by ſtanding.

Sulphur. Is another Name for Brimſtone; but in a more Technical Senſe, denotes the fat, unctuous, or oily Principle in Bodies; or that Part of them, which is truly inflammable.

Thermometer. Is an Inſtrument contrived to meaſure the Degrees of Heat. Thoſe made with Spirit of Wine, ſerve for the leſſer Degrees, and thoſe with Oil, or Quickſilver, for the greater.

Triture. Is the grinding, or rubbing any ſolid Body to Powder in a Mortar, or upon a grinding, or levigating Stone.

Torrefaction. Is the roaſting, or ſcorching, of a Body by the Fire, in order to diſcharge a Part either unneceſſary or hurtful, in another Operation,

ration; as Sulphur is diſcharged from an Ore, before the Metal can be obtained to advantage.

Turnſol. Is a red Colour prepared from the Juice of the Sun-Flower, and fermented Urine: which Colour being, in a fluid State, drank up by Linen-Rags, and dried, is the Thing ſold by the Dry-Salters to the Dyers and the Wine-Coopers, for dying Cloths, and tinging Wines red.

Vitrification. Is the turning of a Body to Glaſs in the Fire.

Waſh. Is the ſame Thing as fermented Wort, or any fermented Liquor, fitted to afford an inflammable Spirit, or Brandy, by Diſtillation.

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LECTURE I.

CONTAINING

I. *An Account of the Office and Objects of* Chemiſtry.
II. *The* Chemical *Treatment of Bodies.*
III. Rules *for making new Diſcoveries in the Art.*

1. THE Deſign of theſe Lectures is to enlarge the Bounds of Chemiſtry, by applying it to the Advancement of Natural Philoſophy, the Illuſtration and Improvement of the known Arts, and the Diſcovery of new ones.

The Deſign.

2. In proſecuting this Deſign we would ſpeak to the Eye, rather than the Ear; or indeed to the Underſtanding, rather than the Senſes; and by means of appoſite Experiments, ſcientifically explained, lead to the Diſcovery of *Phyſical Axioms*, and *Rules of Practice* for producing uſeful Effects, in the way of a *Philoſophical Chemiſtry.*

The Manner of Execution.

3. *Philoſophical Chemiſtry* we define, a rational Art of (1) dividing or reſolving all the Bodies within our Power (2) by means of all the Inſtruments we can procure; (3.) as well into integrant as conſtituent Parts; and (4.) joining theſe Parts together again; (5.) ſo as to diſcover the Principles, Relations, and Changes of Bodies; (6.) make various Reſolutions, Mixtures, and Compoſitions; (7.) find out the phyſical Cauſes of phyſical Effects; and (8.) hence improve the State of natural Knowledge, and the Arts thereon depending.

Philoſophical Chemiſtry defined.

4. To

The Buſineſs of the Lectures. 4. To explain this Definition, in a conciſe general manner, is the Buſineſs of our firſt *Lecture*; and to illuſtrate it fully, will be the Buſineſs of all the reſt.

5. Our Definition conſiſts of eight Parts; the firſt whereof regards the *Objects of Chemiſtry.*

The Objects of Chemiſtry. (1.) Theſe *Objects* are all the Bodies within our Power. We ſhould therefore, if it were practicable, take a particular View of the Contents of the terraqueous Globe. To abridge the Labour, we ſhall ſingle out the more capital and uſeful Sorts; and range them in ſome Order, by way of Specimen, or Sample, of that grand Repoſitory of infinite Materials *.

Claſſed. The Productions of the Earth are divided into, I. *Minerals.* II. *Vegetables*, and III. *Animals.*

I. Minerals are ſubdivided into (1.) Metals and their Ores, (2.) Salts, (3.) Sulphurs, (4.) Stones, (5.) Earths, and (6.) Semi-metals.

CLASS I. The METALS are.

Gold,
Quickſilver,
Lead,
Silver,
Copper,
Iron,
Tin.

Ranged according to their ſpecific Gravities, and compared with their Ores reſpectively.

II. SALTS. *Alum*,
Artificial Salt,
Bay Salt,
Borax,
Nitre,
Rock Salt, or *Sal-Gem*,
Sal Ammoniac.

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* In the Courſe, a Set of Specimens was exhibited, in conformity with the following Liſt.

III. SULPHURS. *Amber,*
Arſenic, white, yellow, and red,
Auripigmentum,
Bitumen,
Brimſtone, Common,
——— ——— *Native,*
Coal,
Jet,
Petreol.

IV. TRANSPARENT STONES.

From the *Diamond* to *Cryſtal.*	Ranged according to their Hardneſs, which is their Criterion, as Gravity is of Metals.

V. OPAKE STONES. *Alabaſter,*
Amianthus,
Emery,
Flint,
Hæmatites,
Loadſtone,
Marble, and Porphyry,
Lapis Calaminaris,
Talc,
Tripoli, &c.

VI. EARTHS. *Bole,*
Chalk,
Marl,
Ore,
Ocre,
Ruddle,
Terra Lemnia, &c.

VII. SEMI-METALS.

The Vitriolic are,

Vitriol, green and blue, *viz.* of Iron and Copper; *White Vitriol*, with other foreign kinds.

VIII. The Sulphureous SEMI-METALS are,
Antimony,
Biſmuth,

Cinnabar, native,
Mundick,
Pyrites,
Zinck, &c.

II. VEGETABLES are divided into
Herbs, Berries, Flowers, Fruits, Grains, Seeds, Roots, Barks, Woods, Juices, and Excreſcences.

Claſs I. HERBS. *Angelica, Baulm, Hyſſop, Roſemary, Lavender, Sage, Tanſy, Thyme, Wormwood,* &c.

II. BERRIES. *Bay Berries, Coffee, Kermes, Juniper,* &c.

III. FLOWERS. *Jaſmin, Saffron, Lillies, Marigolds, Roſes, Elder-Flowers, Violets, Flowers of Broom, Holly-Oak,* &c.

IV. FRUITS. *Cocoa-Nuts, Nutmeg, Jamaica-Pepper, Long-Pepper, Tamarinds, Caſſia Fiſtularis, Pomegranate,* &c.

V. GRAINS. *Rice, Indian Wheat, Sago, Millet,*&c.

VI. SEEDS. *Beech-maſt, Cardamom, Gran. Paradiſ. Muſtard-Seed, Sun-flower Seed,* &c.

VII. ROOTS. *Alkanet, Galangal, Gentian, Liquorice, Madder, Orris, Turmerick,*&c.

VIII. BARKS. *Caſſia, Cinnamon, Clove-Bark, Cortex Peruv. Mace, Oak-Bark, Winter's Bark,* &c.

IX. WOODS. *Cedar, Guaiacum, Logwood, Rhodium, Saunders,* &c.

X. JUICES are ſubdivided into natural, and artificial; or into *Tears*, and *inſpiſſated Juices.*

Tears, or natural Juices, of the Sycamore, the Birch, *&c.*

Inſpiſſated Juices are divided into (1.) *Gums*, (2.) *Balſams*, (3.) *Roſins*, and (4.) *Sugars*.

(1.) GUMS. *Aloes*, *Gum Arabic*, *Aſſa Fœtida*, *Ammoniacum*, *Benjamin*, *Bdellium*, *Galbanum*, *Gamboge*, *Maſtich*, *Myrrh*, *Gum Elemi*, *Opopanax*, *Gum Sandarac*, *Gum Lac*, *Gum Tragacanth*, &c.

XI. (2.) BALSAMS. *Balſam Capivi*, *Opobalſamum*, *Balſam of Peru*, *Tolu*, *&c.* The *Turpentines*, *Wax*, &c.

XII. (3.) ROSINS. *Campbire*, *Frankincenſe*, *Roſin of Guaiacum*, *Roſin of Jalap*, *Scammony*, *Burgundy Pitch*, *Common Roſin*, *Sang. Draconis*, *&c.*

XIII. (4.) SUGARS. *Honey*, *Manna*, *Sugar*, &c.

XIV. EXCRESCENCES. *Jews Ears*, *Agarick*, *Miſletoe*, the *Moſſes*, *Galls*, &c.

III. ANIMALS.

Claſs I. ENTIRE ANIMALS. *Ants*, *Bees*, *Cantharides*, *Cochineal*, *Millepedes*, *Vipers*, &c.

II. THEIR SOLID PARTS *Bone*, *Hart's-horn*, *Ivory*, *Cuttle Bone*, *Elk's Hoof*, *Human Skull*, *Caſtor*, &c.

III. CONCRETED ANIMAL JUICES. *Goat's Blood and human Blood dryed*, *Lard*, *Marrow*, *Sperma Ceti*, &c.

IV. EXCREMENTS. *Album Græcum*, *Civet*, *Muſk*, *Pigeon's Dung*, *Silk*, &c.

Bodies how to be divided.

6. *Bodies* have been uſually conſidered under three general Claſſes, called by the Names of the Vegetable, Animal, and Mineral *Kingdoms*. This Diviſion is, perhaps, too ſcanty; as excluding many Particulars of the marine and atmoſpherical Regions. For in the Sea are found Coral, Shells, Spunge, Bitumen, Ambergreaſe, Mixtures of

Salt, Slime, Fæculencies, and the corrupted Parts of Fiſh, *&c.* which may poſſibly be irreducible to any of the three Kingdoms. And the Atmoſphere abounds with Air, Light, Water, Meteors, Exhalations and Effluvia of the Earth, differently combined; ſo as not to appear diſtinctly either of a Vegetable, Animal, or Mineral Nature.

7. The *Objects of Chemiſtry*, therefore, are taken from the three larger Maſſes, or Regions, of the Globe; *viz.* the *Earth*, *Water*, and *Atmoſphere*

The general Structure of the Earth. 8. Our Knowledge of the *Earth* reaches but a little below its Surface. So far as Men have dug, it appears a Compages of numerous ſolid Subſtances, ranged in a diſorderly manner; which may be phyſically neceſſary, to afford different Partitions, or Beds, of Soil, Gravel, Clay, Stone, Coal, Marcaſites, Ores, Gems, *&c.* each ſerving as a Matrix to the other.

Earth in particular. 9. By *Earth* is commonly meant the Soil, Mould, or Coat, wherein Vegetables grow. This Coat, which is but of little Depth, is the direct and immediate Seat of Vegetation. And with this Earth we chuſe to begin our Experiments; propoſing (1.) A general Analyſis of Garden Mould; (2.) The Preparation of a general kind of Flux, for the aſſaying of Ores. (3.) The general Method of aſſaying Ores for their Metal. (4.) A general Analyſis of common Water. (5.) A general Analyſis of the Air. (6.) A general Example of the Method of reducing Bodies to their integrant Parts. (7.) A general Example of reſolving Bodies into their conſtituent Parts; and (8.) An Example of Reduction, or the Method of recompoſing, or recovering, Bodies after Solution.

II.

EXPERIMENT I.

The Analyſis of Garden Mould, begun.

Earth analyſed.

10. We took two Pounds of freſh, black and rich Garden Mould, and ſtirred it well in two Quarts of fair Water, gently warmed, then letting the groſſer Part ſettle to the Bottom, we filtred the Liquor thro' Cap-Paper; and found that it paſſed conſiderably muddy, or impregnated with the finer Parts of the Earth; which it would not eaſily depoſite upon many Days ſtanding in a quiet Place *.

11. The Deſign of the Experiment is to obtain a proper Liquor for diſcovering the Matter which the Earth affords to Plants in Vegetation, or the natural Juices, and natural Salts, of Garden Mould; becauſe nothing ſeems capable of riſing in Vegetation, but what is ſoluble in moderately warm Water, and will paſs the Pores of Paper, ſomewhat in the ſame manner as it does the natural abſorbing Veſſels, or Strainers of a Plant. Whence the filtred Liquor of our Experiment may be examined by chemical Treatment; as by Evaporation, or the way of trying *Mineral Waters*, &c. as we ſhall ſee hereafter in our fourth Lecture.

12. Ores are the next uſeful Species of *Earth*; the general Treatment whereof, for obtaining their Metal, depends upon the Uſe of the *Black Flux*.

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* See this Experiment carried a greater length in *Lect.* IV. *Exp.* I. and II.

EXPERIMENT II.

The Method of making the Black Flux, for the aſſaying of Ores.

The Black Flux. 13. We took one Part Nitre, and two Parts common Tartar; and reducing each to Powder, we mixed them together, and deflagrated the whole in a Crucible, by lighting the Mixture a-top; which thus turns to a kind of *Alkaline Coal*, that is to be pulverized, and kept in a cloſe Glaſs, to prevent its diſſolving, as it would do in a moiſt Air.

14. This Flux is of general Uſe; and to have it ready at hand, ſhortens the Buſineſs of making Aſſays in Metallurgy; and renders the Operation more exact, than when crude Tartar and Nitre are employed; becauſe the Deflagration might thus carry off ſome Part of the Ore, and defraud the Account. For the ſame Reaſon, the Mixture is here directed to be fired a-top; otherwiſe a conſiderable Part might be loſt in the Deflagration; which would prove much more tumultuous and violent if the Matter was thrown into a red-hot Crucible.

EXPERIMENT III.

The general Method of analyſing Ores.

Ores analyſed. 15. We took two Ounces of Copper Ore reduced to Powder, and mixed it, in a Mortar, with twice its Weight of the black Flux; then, in a Wind Furnace, fuſed it briſkly, that it might run thin, for about four Minutes: when, ſuffering the Crucible to cool, we broke it, beat off the Slag, and weighed the Metal.

16. This Experiment ſhews the Method of treating any unknown Ore, to diſcover, in the

way of Aſſay, or Proof, the Kind and Proportion of Metal it contains.

17. The *Cauſe* of the Effect depends upon a Separation of the terreſtrial, ſulphureous, or other heterogeneous Parts of the Ore, which are here either vitrified, or otherwiſe detained by the Flux; whoſe Property it is to vitrify Earth in the Fire, and ſtrongly join with Sulphur; at the ſame time that it does not alter the Metal, but leaves it to its own nature; whence, by its ſuperior Gravity, it ſinks pure to the bottom of the Crucible; as being now made fluid, and ſet free from the heterogeneous Parts before mixed in among it *a*). *The Rationale of the Proceſs.*

18. *Water* is generally divided into ſalt and freſh, with regard to the Ocean and Rivers. But it ſeems diviſible into as many different Species, as the Earth is into Beds. Thus there are Mineral Waters of various kinds, according to the Mineral Subſtances they run over, and become impregnated with: tho' this Impregnation ſometimes happens in the way of Vapour, or Exhalation. Water, therefore, in the general, may be as mixed a Body, as Earth in the general; and perhaps neither of them naturally exiſts in any conſiderable Degree of Purity *b*). *Water divided.*

EXPERIMENT IV.

A general Analyſis of common Water.

19. (1.) We found that common warm Water throws up numerous Bubbles, and explodes, in the exhauſted Receiver of the Air-Pump; and therefore contains what may, by way of diſtinction, be called Æther or Spirit. *Water analyſed.*

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a) See the Lect. on Metallurgy.

b) See *Lect.* V.

(2.) It contains a merely aqueous part, diſtinct from Æther, and from the Sediment; as appears in diſtilling common Water.

(3.) It contains a dry ſolid Matter, which is either earthy or ſaline, as appears upon a full Evaporation; and alſo from the Inſides of Tea-Kettles, which, after long Uſe, are lined with a ſtony Matter, that beats off in Flakes or Cruſts.

20. That Water is accounted beſt and wholeſomeſt, which is lighteſt, moſt ſpirituous, and freeſt from earthy Sediment; and theſe Properties are uſually found in pure Rain Water: this being naturally diſtilled, or raiſed by the Sun's Heat, from the Ocean and Rivers, into the Atmoſphere, and from thence returned again, much after the manner of common Diſtillation a).

The Atmoſphere divided.

21. THE *Atmoſphere* is a kind of dry Fluid, no leſs eſſential to the Earth than the moiſt one. It ſeems as heterogeneous as the Earth or Water, tho' more rarified. It is diſſimilar in its Parts, like the Body of the Earth; and has ſomething analogous to Beds, or particular Portions abounding with different kinds of Effluvia, according to the Differences of the Countries and Places over which it extends. Thus over Mount *Ætna*, or other *Vulcanos*, it muſt neceſſarily be impregnated, after the manner of certain Mineral Waters, with the Fumes of burning Minerals; over the Iſland *Ceylon*, with Aromatic Effluvia; over *London* with the Smoke of Sea-Coal b), *&c.*

EXPERIMENT V.

A general Analyſis of the Air begun.

The Air analyſed.

22. A proper Analyſis of the Air, or any integrant part of the Atmoſphere, has hitherto ſcarce been attempted.

---

a) See *Lect.* V.

b) See *Lect.* III.

(1.) That it is an elaſtic Fluid appears by its diſtending Bladders, and breaking Glaſſes, in the exhauſted Receiver of the Air-Pump. (2.) That it is eſſential to Life, appears by Animals dying without it. (3.) That it may receive inviſible Influences or Alterations, as well as viſible Effluvia, appears from its becoming poiſonous by paſſing thro' Fire; and by its containing groſs Smoak, and the fine Particles of fermenting or putrefying Bodies: And (4.) that it is naturally a Compound, appears by the Water it depoſites in dry Salt of Tartar; and by its changing the Colours of various Bodies, *&c.*

23. We ſhall hereafter attempt a more particular Analyſis of the *Atmoſphere*, in order to a Choice of the beſt Places for Health, Habitation, and the Exerciſe of particular Arts; on account of certain Properties in certain Places, ariſing from the different Mixtures, or Compoſitions, of the Air in different Parts *a*).

The Inſtruments of Chemiſtry.

24. THE *Inſtruments of Chemiſtry* are all thoſe we can any way procure *b*). There are ſeveral Inſtruments continually at work, for the immediate Production of Effects, in the three larger Maſſes, or Kingdoms, of the Globe, *viz.* the Earth, Water, and Atmoſphere. We evidently find, that Metals and Minerals are formed within the Earth; Vegetables on its Surface, ſhooting into the Air; Meteors in the Atmoſphere; and Men, Beaſts, and Birds in the Confines of the two: The *Phyſical Cauſes* of all which are to be diligently ſought out, as ſo many *Rules of Practice.*

The phyſical Agents of Nature.

25. The principal phyſical Agents in Nature appear to be, (1.) Heat. (2.) Cold. (3.) Air, or the integrant Parts of the Atmoſphere. (4.) Water. And (5.) proper Beds, or *Matrices.* This is

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a) See *Lect.* III.

b) See above §. 3.

Matter of direct Obſervation; and might occaſion the eſtabliſhing of the four common Elements, Fire, Air, Water and Earth.

The Sun. 26. (1.) The *Sun* is the principal Source of Heat upon the Earth's Surface, and the Confines of the Earth and Atmoſphere. Without this, all the Bodies upon our Globe would doubtleſs grow rigid, lifeleſs, and fixed. 'Tis this that ſtirs within them, as the main Spring of their Actions. Hence Vegetation, and Animalization, are evidently promoted; and hence the Ocean and the Atmoſphere continue in a fluid State *a)*.

[illegible]d. 27. (2) *Cold* is correlative to Heat; and tho' perhaps no more than a leſs Degree, or Abſence, thereof, yet has, in the natural State of things, an inſtrumental Efficacy; as in the condenſing of Solids *b)*, the coagulating of Fluids *c)*, the ſeparating of Salts *d)*, Spirits *e)*, *&c.* And by means of Cold and Heat, uſed alternately, it ſhould ſeem that ſome capital Operations of Nature are performed, eſpecially in the vegetable Kingdom, by the Reciprocation of Day and Night, Summer and Winter *f)*.

Air. 28. (3.) Air, or any integrant Part of the Atmoſphere, is an elaſtic Fluid, that expands with Heat, and contracts with Cold; ſo as apparently to generate Motion, and produce Effects. It animates Fire, and has a great Influence upon the Life of Animals: it alſo mixes in among, and unites itſelf with, Bodies; ſo as to conſtitute a material Part thereof *g)*. It is the great Receptacle of

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a) See *Lect.* II. *paſſim.*

b) Which are rarified by Heat, but contracted by Cold.

c) As aqueous Liquors into Ice.

d) As Salt is ſeparated in the Freezing of Salt-Water.

e) As Spirit is ſeparated in the Freezing of Wine, urinous Spirits, and diſtilled Vinegar.

f) See *Lect.* III.

g) See *Lect.* III.

Effluvia from the Earth, the Matrix of Meteors, the continual Support of Birds, Beaſts, Plants, and Men; and is in ſome degree nutrimental *a)*.

29. (4.) *Water* is not only contained in the Earth, as in a Reſervoir, but likewiſe floats in the Atmoſphere. In both Caſes it is actuated, rarified, and put in motion by Heat; ſo as to prove inſtrumental in producing Effects. Thus it produces Clouds, Rains, Dews, Springs, and Rivers. It refreſhes the Earth, recruits Vegetables, and is the Support of Fiſh and other Animals, by conveying Nutriment to all their Parts. It is alſo the firſt and immediate Inſtrument of Fermentation, Putrefaction, Corruption, and Change, in all vegetable and animal Subjects *b)*. *Water.*

30. (5.) Proper Beds, or *Matrices*, alſo appear to have an inſtrumental Agency in the Production of natural Bodies. Every Subject of an Operation is neceſſarily contained in ſomething that may (1.) afford it a Lodgment, (2.) make ſome Reſiſtance, and (3.) convey to it Heat, Cold, Water, or Air, or determine their Actions upon it. Thus in Vegetation, the Matrix Earth ſupports the Seed, reſiſts its Swelling, and conveys a ſtrained, or prepared, Moiſture to it. The *Matrices* of Gems and Ores not only afford a proper Lodgment to the Subject-Matter, but alſo reſiſt its Growth, by the Preſſure of their Sides; which, however, give way a little, and at the ſame time ſtrain and convey ſuitable Juices to the Subject. And ſomething of this kind is obſerved of the *Fœtus in Utero*, the Hatching of Eggs, *&c.* inſomuch that Cloſeneſs, moderate Reſiſtance, or a ſlow yielding of the Sides of the Matrix, and a ſtraining of the Juices through them (unleſs ſupplied *Matrices.*

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a) As it adds to the Subſtance of Vegetables and Animals. See Mr. *Hale's Vegetable Staticks*, and hereafter *Lect.* III.

b) See *Lect.* VII and XII.

plied from within) ſeem requiſite for the Formation and Production of all Vegetable, Animal, and Mineral Subſtances. Whence we are furniſhed with a capital Rule for the Improvement of Chemiſtry, natural Philoſophy, and Arts; and taught that, in order to imitate Nature, Chemiſtry muſt not be confined to the ſole Uſe of Fire, as its Inſtrument, but occaſionally employ Water, Cold, Air, Earth, and proper *Matrices*, or Veſſels.

Artificial Inſtruments of Chemiſtry.

31. But beſides theſe *natural Inſtruments*, there is a great Variety of *artificial* ones belonging to Chemiſtry, which ſeem to raiſe the Power of this Art, in ſome reſpects, above the Power of Nature. Thus, by means of particular Menſtruums, it performs Operations which Nature of herſelf does not: for inſtance, of all the Metals, only Iron and Copper are found naturally converted into Vitriol; whereas Chemiſtry makes Vitriols even of Gold, Silver, Tin, and Lead. And hence the Productions of Art may be much more numerous, than the Productions of Nature; indeed they may be increaſed at pleaſure, to the great Enrichment of Arts, and the Enlargement of the Kingdom of Man a).

Veſſels, Furnaces, Utenſils.

32. Another Set of Inſtruments belonging to Chemiſtry are *Veſſels*, *Furnaces*, and *Utenſils*; of which there is a great Variety, for different Purpoſes, and capable of producing numerous Changes in Bodies, by Amalgamation, Cementation, Fuſion, Fermentation, Putrefaction, Reduction, &c.

A new Set.

33. We add to the above-mentioned a new Set, *viz.* The *Air-Pump*, the *Condenſer*, *Digeſtor*, *Microſcopes*, *Burning Concaves*, *Priſms*, *Lenſes*, *Portable Furnaces*, and every other Inſtrument that can be invented, or procured, of advantage to the Art.

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a) In this Light may the numerous Productions of the Chemical Trades be conſider'd; ſuch as the Effects of Fermentation, Diſtillation, Dying, Soap-making, the Art of Glaſs, Metallurgy, &c.

34. THERE are two capital Ways wherein Chemiſtry divides its Subjects, by the ſeveral Inſtruments above-mentioned; *viz.* into *integrant Parts*, and into *conſtituent* Parts. By *integrant* Parts we underſtand ſimilar Parts, or Parts of the ſame nature with the Whole; ſo Filings of Iron have the ſame Nature and Properties as Bars of Iron. Under this general Operation, fall thoſe particular ones of Triture, Filing, Solution, Amalgamation, Sublimation, *&c.* And by *conſtituent Parts*, we mean diſſimilar Parts, or Parts of a different Nature from the Whole; as when artificial Cinnabar is divided into Quickſilver and Sulphur: and under this general Operation come all kinds of Analyſes or Reſolutions.

Two principal kinds of chemical Diviſion.

EXPERIMENT VI.

A general Example of reducing Bodies into their integrant Parts.

35. We took an Ounce of Quickſilver in a ſmall Glaſs, and poured upon it two Ounces of *Aqua fortis*; then ſet the Glaſs in a Sand-Heat to warm: red Fumes ſoon appeared; and the Mercury, or Quickſilver, diſappeared. We added a little more Mercury, till a ſmall Particle was left undiſſolved at the Bottom, that the Solution might be ſaturated. Then we decanted the clear Liquor: a Drop of which being viewed in a Microſcope no Particles of the Mercury appeared ſeparate.

Quickſilver rendered inviſible by a minute Diviſion into integrant Parts.

36. Here we find the opake and heavy Body of Mercury tranſparently diſſolved, and equally diffuſed in a Fluid, at leaſt ten times lighter than itſelf; the Mercury ſtill remaining unaltered and recoverable in its priſtine Form, barely by Collection or Aggregation, as we ſhall preſently ſee *a)*: ſo that it is thus only divided into homogeneous

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a) Under Experiment VIII.

geneous or integrant Particles, and not ſeparated into Particles of different Kinds.

EXPERIMENT VII.

A general Example of reſolving Bodies into their conſtituent Parts.

Brandy reſolved into its conſtituent Parts.

37. We gently diſtilled two Gallons of common Brandy by the *Balnæum Mariæ*, which reſolved it into Spirit of Wine and Water. For the Spirit of Wine, being the lighteſt Part, comes over firſt, and leaves a large Proportion, or about one half, of Water or Phlegm in the Still.

38. And thus Brandy is ſeparated into the two very different, or heterogeneous Parts, whereof it conſiſts. And hence, by the way, all Rums and Brandies contain one half Water, no way eſſential to them, that might commodiouſly be left behind upon their Tranſportation and Carriage. And this holds ſtill ſtronger of Arracks, which uſually contain three fourths Water, to one of Spirit *a)*.

Aggregates and Mixts, what.

39. Theſe two general Operations of Chemiſtry bear relation to two general Structures of Bodies, *viz*,. the *Aggregate* and the *Mixt*. Aggregates in their Reſolution conſtantly retain their Nature in every the ſmalleſt Part, or Atom; but when Mixts are reſolved, the Mixture is deſtroyed, and two or more new Aggregates are produced: thus when Brandy is reſolved, Spirit of Wine or *Alcohol*, and *Water* are produced.

Senſible Bodies compoſed of inſenſible.

40. Every ſenſible Mixt, or Aggregate, is compoſed of many inſenſible ones. Before Gold can become ſenſible to us, there muſt be a Collection of numerous Parts that are ſeparately inſenſible; yet all of them perfect Gold. The

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a) See *Lect*. VII. Exp. IV. and *Lect*. XII. Exp. IV.

minuteſt Grain of Cinnabar has in it two different Parts, Sulphur and Quickſilver. The minuteſt Grain of Glaſs contains Sand and fixed Salt. And ſo when Quickſilver is diſſolved in *Aqua Fortis*, the leaſt aſſignable Portion of the Menſtruum contains a Quantity of Mercury proportionable to the whole.

Recompoſition illuſtrated.

41. (4.) Either he integrant or the conſtituent Parts of Bodies being once divided or reſolved *a)*, various Occaſions in Chemiſtry require them to be united again, for compoſing a Whole like the original Subject. This Operation is the Converſe of the former. Thus by ſimple Mixture we recompoſe Brandy from Alcohol and Water; and by Precipitation with a Copper-Plate, collect the Quickſilver diſperſed in *Aqua Fortis*.

EXPERIMENT VIII.

An Example of the Method of recovering Bodies after Solution.

Quickſilver recovered.

42. Dilute part of the above Solution of Quickſilver *b)* with twice its quantity of fair Water; ſuſpend a Plate of Copper in the Liquor; the Quickſilver will ſoon fall in its natural Form to the bottom of the containing Glaſs, and being then taken out, well waſhed and dried, will be abſolutely indiſtinguiſhable from other Quickſilver that has never been diſſolved. The Effect is owing to this, that *Aqua Fortis* diſſolves Copper more eaſily than Quickſilver, and ſo lets the Quickſilver fall in proportion as it diſſolves the Copper. And this, by the way, is a general Example of *Precipitation*.

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a) See above, §. 3.

b) Exp. vi.

The Principles, Relations, and Changes of Bodies, how diſcoverable.

43. (5.) To diſcover the Principles and the Relations of Bodies, and the Changes a) produced in them by the Operations of Philoſophical Chemiſtry, we muſt uſe all our Senſes, aſſiſted by proper Sets of Experiments, or particular Ways of Examination; otherwiſe we ſhall learn but little of the Powers of Nature and Art. In the Experiment of Quickſilver diſſolved in *Aqua Fortis*, we find by a ſlight Expedient, *viz.* by putting a piece of Copper into the Solution, that the Quickſilver, tho' rendered inviſible, is not deſtroyed; ſeeing it is thus recovered in its priſtine Form and Properties.

44. By caſual Experiment, *Glauber* diſcovered his Method of preparing mineral acid Spirits by means of Oil of Vitriol: for having once obtained this Oil, by an Analyſis of Vitriol, he applied it to the Mineral Salts, and found that it expelled their volatile Acids in Fumes; and that theſe being more plentifully raiſed by Heat, and collected again, made the acid Spirits, ſo uſeful in Metallurgy, Refining, Dying, *&c.* Thus one new chemical Production may give Riſe to many new Arts.

The Reſolutions and Compoſitions of Chemiſtry.

45. (6.) The Reſolutions and Compoſitions made by Chemiſtry b) are extremely numerous, and may be increaſed *ad infinitum.* We exhibited an Inſtance of Reſolution in the Analyſis of Brandy: And to this Claſs of Reſolutions are referable all kinds of Depurations, Purifications, Separations, Clarifications, *&c.*

The Productions of Compoſition.

46. By Compoſition we produce all the artificial Vitriols, Soaps, Glaſſes, *&c.* and can compound theſe again in an almoſt infinite Variety. So that the Reſolutions, Compoſitions, and Recompoſitions in Chemiſtry, ſeem to have

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a) See above, §. 3. b) Ibid.

no Bounds; whence great room is left for new chemical Diſcoveries.

47. (7.) Whilſt we carefully attend to the ſeveral Steps of chemical Operations, we are led into ſome ſort of Knowledge of the *Phyſical* or *Material Cauſes* of the Effects *a)* produced, as may appear from our Attempts to aſſign the chemical *Cauſes* in the foregoing Experiments. Hence the more Attention and Diligence we employ, the juſter Notions ſhall we have of theſe Cauſes, or the nearer Approaches ſhall we make to the Diſcovery of them; and they being once certainly found will afford us certain *Rules of Practice*, to be occaſionally employed for producing the ſame Effects again. For to diſcover the Cauſe of an Effect, is to diſcover a Rule for producing that Effect.

The Phyſical Cauſes of chemical Effects.

48. (8.) The Improvement of natural Knowledge, of Chemiſtry itſelf, and of the Arts thereon depending *b)*, muſt be the Conſequence of a due Proſecution and Improvement of *Philoſophical Chemiſtry*; which for Diſtinctneſs ſake, we ſhall hereafter conſider, as it more immediately relates to (1.) *Fire*, (2.) *Air*, (3.) *Earth*, (4.) *Water*, (5.) *Menſtruums*, (6.) *Fermentation* and *Putrefaction*, (7.) *The Analyſis of Bodies*, (8.) *The Syntheſis of Bodies*, (9.) *Vegetable Curation*, (10.) *Vinous* and *acetous Fermentation*, (11.) *Diſtillation*, (12.) the making of *Oils*, (13.) *Salts*, (14.) *Colours*, *Dyes*, and *Stains*, (15.) *Pharmacy* and *Medicine*, (16.) *Mineralogy*, (17.) *Metallurgy*, (18.) *Pyrotechny*, and (19.) the farther *Uſes of Chemiſtry*: ſo as to ſhew what has already been done on theſe Subjects, carry the View ſomewhat further, and recommend a fuller Proſecution to others.

The Advantages of improving Chemiſtry.

The Subjects to be treated in the following Lectures.

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a) See above, §. 3. *b)* Ibid.

Three general Rules for conducting Philoſophical Chemiſtry.

49. It was ſaid in our Definition *a)*, tha Philoſophical Chemiſtry is a *rational Art*; by which we mean that it may be conducted by Rule, and need not be left to accidental Trial and caſual Experiment. The Rule for duly conducting the Art we would endeavour to comprize under the following three.

III.

RULE I.

50. *When a Body is offered, in order to have new Properties diſcovered in it, different from thoſe general ones of Figure, Gravity, Elaſticity,* &c. *which come under Mathematical Conſideration, let the Body be reſolved, by degrees, into the ſimpleſt conſtituent Parts, which it is capable of being ſeparated into by the Inſtruments above deſcribed: And let Trial be made with each particular part on a variety of Bodies, according to ſome Analogy of a previous Chemical Knowledge, leading from one thing to another, in a ſure or probable Method of Ratiocination.*

RULE II.

51. *Let the ſeveral Parts, obtained by the preceding Analyſis, be reunited, beginning with two, and proceeding gradually to the whole Number; uſing at firſt the gentleſt, then the intermediate, and at laſt the higheſt Degrees of Heat and Cold. Thus, for example, join the fixed Salt and Oil of a Plant together, firſt by ſimple digeſtion, and afterwards by boiling; which affords a third Production diſſimilar to all the reſt, and known by the Name of* Soap. *So, again, melt the ſame fixed Salt with the Earth of the Plant; and this will afford Glaſs.*

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a) See above, §. 3.

Let the laſt Attempt be to reunite all the ſeparated Parts of the Body; in order, if poſſible, to form the original Subſtance again.

RULE III.

52. *In every Operation performed let the greateſt Diligence and Exactneſs of Obſervation be uſed, with regard to all the principal Phænomena and Effects produced; let theſe Phænomena be duly regiſter'd, tabled, conſidered, and compared together, after the ſtricteſt Geometrical Manner; the Reſult whereof, if there be no conſiderable Errors committed, will lead to a Knowledge of the ſecret Springs, Motions, Inſtruments, and Means made uſe of by Nature for producing Effects. And thus, with proper Care and Application, juſt* Canons *or Rules of Practice may be formed.*

53. The Art of Chemiſtry having been but little cultivated in this view, all we can at preſent pretend to, is to make ſome Offers at forming ſuch *Canons* or *Axioms*, and conſign them over to further Experience and Obſervation, to be thereby *verified*, *amended* or *rejected*. But if a competent number of juſt *Axioms* and *Canons* were once formed in this manner, others of a ſtill higher nature might be raiſed from them; till at length, Practice and Experience would lead us to a true Theory; and that Theory back again to a more extenſive and uſeful Practice.

IMPERFECT AXIOMS, or CANONS, deduced from the preceding Enquiry, for promoting farther Diſcoveries and Improvements in chemical and natural Knowledge.

54. (1.) *We may learn from our preſent Enquiry, that a true Chemiſtry (as it may perhaps be juſtly called) is exerciſed by Nature in the Vegetable, Animal, Mineral, Marine, and Atmoſpherical Regions; and that by it all Bodies are produced, converted, renovated, repaired, and maintained: and that in the exact Diſcovery, Imitation, and Controul of this* natural Chemiſtry, *conſiſts the Perfection of the* artificial *a*).

(2.) *That neither the Eye, nor all the Senſes together, can give us any Information of the latent Properties of Bodies, their Natures and Uſes, without particular Tryals and Experiments, well attended to and conſidered b*).

(3.) *That Experiments are but inſignificant Facts, unleſs they have a direct Uſe in Life, or tend to the raiſing of* Axioms *and* Canons, *for improving our Knowledge, and extending our Power over the Works of Nature c*).

(4.) *That he who can chuſe fit Subjects, place them in proper* Matrices, *or including Veſſels, and ſupply them duly with Air and Water, Heat and Cold, may probably produce great effects in Imitation of Nature d*).

(5.) *That nature points out three Matrices for producing Phyſical Effects, different in Fineneſs,* viz. *Beds of Earth, Beds of Water, and Beds of Atmoſphere: Beds of Earth for Minerals, of Water for Fiſh, and of Atmoſphere for Birds,*

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a) See above, §. 7, 8, 9, 21, 24, 25.
b) See above, §. 35, 36, 38, 39, 41.
c) *Paſſim.*
d) See §. 24, 25, 26, 27.

&c.

&c; *The Confines of the Earth and Atmoſphere for Plants and Animals; and a rarified Mixture of all Matters for Meteors. a)*

(6.) *That Men may make uſe of the ſame Inſtruments as Nature does,* viz. *Fire, Air, Water, and Earth, and conſequently produce the ſame kind of Effects, if Skill, that is, Knowledge, be not wanting. Whence to improve in Knowledge, is to improve in Arts b).*

(7.) *That Chemiſtry is not confined to the Uſe of Fire only; but, in imitation of Nature, may employ Cold, Air, Water, and Earth upon Matter, in various Degrees of Simplicity, Combination, and Mixture; which ſhews an extenſive Method of enlarging the Bounds of the Art c).*

(8.) *That Fire is not only an Analyſer in ſome Caſes, but alſo a Mixer of Bodies in others; and this to the Advantage of Chemiſtry: For if it only ſeparated, it could produce but few Effects, in compariſon of that infinite Variety it now produces, both by Mixture and Separation d).*

(9.) *That it might be proper to try the Reciprocation of Heat and Cold in Chemical Operations, after the manner of Nature, in Day and Night, Summer and Winter e).*

(10.) *That Body, in all its Forms, is the Object of Chemiſtry; not conſidered mathematically, nor mechanically, but operatively and effectively f).*

(11.) *That the Atoms, or primary ſmall Corpuſcles of Bodies, are inſenſible to us: Thus the firſt Particles of Gold, Salts, Metals and Minerals may float in the Air, and not be perceived by us,*

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a) See § 25. *b)* See § 25, 26, 27. *c)* Ibid. *d)* See § 28—45. *e)* See § 25. *f)* See § 3. 5, 7, 49, *& alibi paſſim.*

till

till they aggregate or are collected together, and make a ſenſible Maſs, or produce a ſenſible Effect a).

12. *That ſome Operation of the Mind is requiſite to digeſt, methodize, and regiſter Chemical Experiments and Obſervations; without which we cannot come to know the Laws obſerved by Nature in Phyſical Operations, nor be able to imitate them: The Chemiſtry, or regular Proceſſes, of the Mind being here as neceſſary, as the corporeal Operations themſelves b).*

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a) See §. 35, 36, 38, 39, 41.
b) See §. 3, 48, 49, 50, 51.

More *Canons* and *Axioms* might be drawn both from the preſent *Lecture*, and from all the following; but the Deſign of drawing any at all, is chiefly to recommend the Method, rather than the Matters brought a ſecond time under conſideration.

LECTURE II.

CONTAINING

I. *The Nature, Properties, Office, and Uſe of* Fire *in general.*
II. *The Nature of Celeſtial, Subterraneous, and Culinary* Fire.
III. *The Effects of* Fire *on the Atmoſphere, and Bodies of the terreſtrial Globe.*
IV. *The Degrees of Heat regulated.*

I.

1. OUR preſent Deſign is to ſearch into the Nature of Fire: This we ſhall attempt by means of Experiments, conducted after the manner laid down in our firſt Lecture. *The preſent Deſign.*

2. All the phyſical Knowledge we can have of a Subject muſt ariſe from attending to its Properties and Effects. But theſe Properties and Effects can never be diſcovered without the help of Experiments, which in phyſical Enquiries are the only Interpreters between our Senſes and our Reaſon. Whence all thoſe Notions of Fire ſhould be rejected as precarious and unſound, that are taken from the direct Teſtimony of the Senſes only, or from bare Reaſoning unaſſiſted by Experiments. In this Enquiry, therefore, the Mind is carefully to be kept unprepoſſeſſed, and to wait for a full and proper Information before it pronounce. *Preliminary Obſervation.*

3. By the general Name of *Fire* Men ſeem to underſtand a certain Senſation, or complex Notion *Fire, how underſtood.*

tion of Light, Heat, Burning, Melting, &c. This Notion ſhould be reſolved or analyſed, in order to ſee what Parts thereof are eſſential, and what precarious or arbitrary.

The Eye no judge of Fire.

4. We frequently find the Effects of Fire produced where no viſible Fire appears. Thus the Fingers are eaſily burnt by an Iron heated below the Degree of Ignition, or ſo as to be no way viſibly red-hot or fiery; whence the Eye is no Judge of Fire.

The Touch no true judge thereof.

5. So likewiſe the Touch gives us no poſitive notice of any Degree of Fire below the natural Heat of the Body, or of any ſo great as to deſtroy the Organ.

Burning, &c. not eſſential to Fire.

6. Again, the Effects of Fire are often produced without any manifeſt Signs of Burning, Melting, &c. as in Evaporations, Exſiccations, &c.

7. If this Method of Excluſion and Rejection were purſued to its due length, we ſhould perhaps find no Criterion, infallible Mark, or Characteriſtick of Fire in the general, but that of a particular Motion, ſtruggling among the ſmall parts of Bodies, and tending to throw them off at the Surface. If this ſhould prove the Caſe, then ſuch a Motion will be the *Form* or Eſſence of *Fire*, which being preſent makes Fire alſo preſent, and when abſent makes Fire alſo abſent. Whence to produce Fire, and to produce this Motion in Bodies, will be the ſelf-ſame thing *a)*.

8. But the following Experiments will afford us more Light, and ſhew, (1.) That, in general, both Solids and Fluids manifeſt an expanſive Motion upon being heated; (2.) That the direct inflammable Matter of Fuel is Oil, or an unctuous

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a) See Lord *Bacon*'s Philoſophical Works, Engliſh Ed. Vol. II. pag. 433, &c.

Subſtance; (3.) That no Fuel will burn or conſume without the Admiſſion of freſh Air; (4.) That the Air, which has once paſſed through burning Fuel, is of itſelf unfit to animate Fire again; and, (5.) That Flame exiſts only on the Surface of Fuel.

EXPERIMENT I.

That Iron expands with Heat.

9. We procured an Iron Ring to be made, juſt capable of admitting one end of a ſolid Rod of the ſame Metal; then heating that End in the Fire till it was red, and applying it to the Ring, we found the Rod ſo ſwell'd, that it would not now enter the Hollow which it fitted exactly when cold.

10. This Experiment directly ſhews no more than that Iron expands upon being heated; but as it has alſo been found to ſucceed in many other Solids, it may be made general, till the contradictory Inſtances are produced in the way of Exceptions *a)*.

EXPERIMENT II.

That Fluids expand with Heat.

11. We filled the ſpherical Cavity of a bellied Glaſs, having a long and ſlender Neck, at three different times, with (1.) Mercury, (2.) Water, and, (3.) Spirit of Wine, to the ſame height; then plunging the Glaſs, ſucceſſively, into Water (kept in the ſame Degree of Heat, in all the three Trials, as appeared by a Thermometer) we found that each Fluid ſwelled very remarkably, or roſe up to a conſiderable Height in the

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a) Cedar Wood has, upon ſome Trials, been thought not to expand with Heat, or contract with Cold.

the Neck of the Glaſs, above what it ſtood at before the Glaſs was placed in the hot Water.

12. This Experiment ſeems to hold of Fluids univerſally: ſo that for the preſent we may allow the Motion of Expanſion, or Rarifaction in Bodies, to be inſeparable from Heat, or Fire in the general.

II.

Three Kinds of Fire.

13. We proceed to conſider this *general Fire* in its three Kinds, *viz. Celeſtial*, *Subterraneous*, and *Culinary*.

Celeſtial.

15. By *Celeſtial Fire* we principally mean that of the Sun, without regard to the Fire of the fixed Stars; tho' this perhaps may be of the ſame nature.

Subterraneous.

15. By *Subterraneous Fire* we underſtand that which manifeſts itſelf in fiery Eruptions of the Earth, Vulcanos, or burning Mountains; and by any other Effects it produces in Mines, or the more central Parts of the Earth.

Culinary.

16. By *Culinary Fire* we mean that vulgarly employed in all Chemical Operations, and the common Occaſions of Life.

The Sun's Heat.

17. The Sun's Heat appears to be the actuating Principle, or general Inſtrument of all the Operations of Nature in the Animal, Vegetable, Atmoſpherical, Marine, and Mineral Kingdoms *a)*.

The Purity of the Sun's Heat.

18. Conſidered in itſelf, Fire ſeems to exiſt in greateſt Purity and Perfection in the Celeſtial Regions; at leaſt we are not ſenſible of any Smoke it yields: for the Rays of Light come to us from the Sun, unmixed with any of that groſs, terreſtrial Matter found in Culinary and Subterraneous Fires. But allowing for this Difference

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a) See *Lect.* I. §. 16.

the Effects of the Solar and Culinary Fire appear to be the ſame.

19. The Effects of *Subterraneous Fires* will alſo be found nearly the ſame with thoſe produced by Culinary Fire. Burnt Coals, Cinders, and melted Minerals are thrown up by *Veſuvius*, and other Vulcanos. Warm mephitical Exhalations, natural hot Springs, Steams, Vapours, Smoke, *&c.* are found in ſeveral parts of the Globe, riſing much in the ſame manner as if they were produced by the Heat of a Furnace. Whence it can ſcarce be doubted that Subterraneous Fires are of the ſame nature with the Culinary. *Subterraneous Fire approaches the Culinary.*

20. And as all the three kinds agree in giving the Motion of Rarifaction to Bodies, it ſeems no way improper to reduce them to one; or to quit, for the preſent, the Celeſtial and Subterraneous, and keep to the Culinary Fire, which is more within our power, and every where ready at hand to be employed in Experiments. *The three Kinds have a near Agreement.*

21. All Culinary Fire requires ſome Pabulum or Fuel, wherein it either reſides or is collected. A leading Experiment therefore, in our preſent Enquiry, is the Analyſis of Fuel; to diſcover its conſtituent Parts, and learn which of them is more immediately adapted to receive or propagate Fire. *Fuel what.*

EXPERIMENT III.

That Oil is eſſential to Fuel.

22. We put a Pound of common Billet-Wood, reduced to ſmall Pieces, into an earthen Retort, and diſtilled with a naked Fire into a large Glaſs Receiver. There came over (1.) an acid Water, (2.) a rediſh tart Liquor, (3.) Smoke, and a groſs *A leading Experiment.*

groſs, black, burnt Oil. The fire being made and kept up ſtrong at laſt, no more Liquor or Oil aſcended; but (4.) a black Matter, exactly reſembling Charcoal, remained behind: this being taken out and burnt in the open Air, fell into Aſhes; which by Diſſolution in Water afforded (5.) a little fixed Salt, and (6.) an earthy Subſtance.

That Coals owe their Inflammability to Oil.

23. This Experiment appears to be general, or to ſucceed alike in all Wood, Coals, or ſolid Fuel. We ſeparated the acid Water or reddiſh Liquor from the Oil by the Filtre; and then found that theſe aqueous Liquors would not burn in the Fire; no more would the Aſhes, the Salt, or the Earth, either ſingly or in compoſition: ſo that of all the Subſtances thus obtained from the Wood, the black Coal and the Oil are the only inflammable ones. But the Coal remains inflammable merely upon account of the groſs Oil ſtill lodged and cloſely locked up therein, and according to its peculiar nature, ſcorched, or turned black by the Heat employed in the Operation.

24. If farther Evidence be wanted to prove that the Oil remaining in the Coal gives it its Blackneſs and Inflammability; let it be conſidered, (1.) That all ſcorched Oils turn black; and that the more volatile Oil, which here comes over into the Receiver, is black. (2.) That no other part of the Wood, ſeparated by the Analyſis, is inflammable, beſides the black Oil; not the Coal itſelf after it is become white or reduced to Aſhes by open Fire and Air, which is an Operation ſufficient to diſlodge the groſs black Oil, that could not be raiſed by a leſs Force. (3.) That no other chemical Cauſe can well be aſſigned for this Blackneſs and Inflammability. (4.) That Wood, Pit-Coal, *&c.* prove leſs imflammable,

mable the more they are deprived of their Oil. (5.) And laſtly, that the Calces of Metals, rendered abſolutely uninflammable by Calcination, appear to attract this Oil out of burning Fuel, ſo as thence to recover their inflammable Principle and true metalline Form a).

25. But without farther Proof we may venture, for the preſent, to conſtitute Oil the ſole Principle, or inflammable Matter in Fuel; and on this footing it will be proper to reduce our Enquiry to the more oily Species of Bodies, and make our Experiments chiefly upon thoſe.

EXPERIMENT IV.

That Fire will not conſume Fuel without the Admiſſion of Air.

26. Having exactly fitted a hollow Cylinder of Iron with a ſtrong Skrew at each end, we included a long Piece of Charcoal in the Cavity; then ſkrewing both ends tight, we detained the Cylinder in a ſtrong Fire for ſeveral Hours; letting it afterwards cool and taking out the Charcoal we found it ſtill black and no way apparently conſumed, altered, or diminiſhed.

27. This Experiment, compared with the common Obſervation that Fuel burns and conſumes quickly in the open Air, ſhews that Air is neceſſary to the Conſumption of Fuel; or that its burning and conſuming depend upon the Rarifaction, Diſlodgment, briſk Agitation, and Diſcharge of the Oil it contains; which is the phyſical Cauſe of the Effect. And hence we have the

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a) Let proper Trial be made, whether the fixed Oil cannot be ſeparated from powdered Charcoal by a ſtrong Lixivium of Pot-aſh and Quicklime, ſo as to form a Soap, or otherwiſe exhibit this Oil to the Eye. See *Lect.* XVIII. §. 22.

reaſon of the known Rule or Method of extinguiſhing Fire by ſmothering it, or keeping it cloſe from the Air.

28. But that the bare Motion of confined Air, or its paſſing ſeveral times through lighted Fuel, is not capable of conſuming it, appears by the following Experiment.

EXPERIMENT V.

That Air which has paſſed thro' Fire , *or ignited Fuel, is unfit to animate Fire again.*

29. We cauſed a wooden Box to be made, perfectly cloſe and tight, with Glaſs Windows on the ſides. At the bottom of this Box was a Perforation exactly fitted with a hollow wooden Plug, that joined to a tight leathern Pipe. This Pipe at the other end communicated with the Clack of a pair of Hand-Bellows, the Noſe whereof entered at a Hole on one ſide of the Box; ſo that by this Contrivance it was eaſy to draw the Air out of the Box into the Cavity of the Bellows, and return it into the Box again, without admitting any other Air beſides that originally contained in the Box. We now ſet a little Chafing-Diſh of live Coals in the middle of the Box, and ſecuring all the Joints tight from the external Air, we plied the Bellows; which, inſtead of increaſing, ſoon totally extinguiſhed the Fire; tho' the Coals were by no means burnt to Aſhes, but remained black and freſh when cold.

30. Hence it is manifeſt, that even a briſk Motion of ſuch Air as has already paſſed through burning Fuel, is ſo far from animating, that it deadens or quenches Fire *a)*, in the ſame manner

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a) Let a proper Experiment be deviſed, to ſhew what Alteration the Air ſuffers by paſſing through Fire.

damped or ſmothered; the Oil of the Fuel not being carried off for want of freſh Air.

31. This method of damping Fuel, or ſuffering it firſt to burn a little and then extinguiſhing it, teaches us a Method of rendering Fuel inoffenſive and fit for the more curious Uſes, by diſcharging its groſs Smoke, ſo as to leave a pure charred Coal behind. *Fuel, how charred.*

Thus for example, if Pit-Coal or Wood be burnt, not in the open Air, but with a cover'd, cloſe, or mouldring Heat, till it ceaſes to fume, and be then immediately quite ſmothered or quenched by throwing on it Mould, Sand, or Water, it becomes a charred Coal or Coak, fit for the drying of Malt, or other curious Operations in which groſs Smoke would be prejudicial.

32. Another Method of obtaining a pure Fuel is to chuſe ſuch an inflammable Matter as yields little or no Smoke from the firſt; ſuch, in particular, is Spirit of Wine; or, in the next Degree, Oil of Turpentine, or other thin *ethereal Oils*, as they are called; whereof Spirit of Wine is by the Chemiſts deſervedly reckoned the fineſt or moſt ſubtile *.

EXPERIMENT VI.

That Flame dwells and plays only about the Surface of Fuel.

33. We filled a Lamp-Glaſs with Spirit of Wine, and another with Oil of Turpentine; then ſetting fire to each it was viſible thro' the Glaſſes that both Liquors burnt or flamed on the Surface only; the Flame continually ſinking lower and lower in the Glaſſes as the Liquors conſumed.

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* See *Lect.* VI. and XIII.

34. This Experiment holds alſo of ſolid Fuel, and appears to be univerſal. And hence again we are directed in the choice of our Fuel; which, to light quick, ſhould be furniſhed with a thin ſubtile Oil on its Surface. Upon this principle depend thoſe ſudden Methods of Illumination practiſed at great Entertainments or publick Rejoicings; and upon the ſame Principle we might eaſily invent quick, commodious, and inoffenſive Ways of lighting common Fires, *&c.*

III.

The Effects of Fire. 35. Having learned how to procure, prepare, manage, and improve our Fuel *a)*, we come next to conſider the Effects of Fire, produced by means thereof, on the Atmoſphere and Bodies of the terreſtrial Globe.

On the Atmoſphere. 36. All Fire rarefies the Air that is near it, as appears from a Bladder including a ſmall Portion of Air, and lying in a warm Place; for thus the Air is made to ſwell and diſtend the Bladder: Whence the Atmoſphere muſt needs be rarefied by the Sun's Heat, and produce Effects accordingly. The Air alſo imbibes Smoke and carries it aloft, at the ſame time that the Fuel diminiſhes or waſtes and falls into Aſhes. Whence the Air becomes a kind of Menſtruum, impregnated with Smoke or the matter of Soot, in Places where much Fuel is conſumed *b)*.

On particular Bodies. 37. The Effects of Fire upon particular Bodies can only be learned from particular Experiments; to make which, is the more immediate Office and uſe of Philoſophical Chemiſtry. Thus in ſome Bodies, as Ores, Fire procures Fuſion

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a) See above, §. 25, 26, 27, 28, 29, 31, 32, 33, 34.

b) See *Lect.* III. *paſſim.* See alſo *Lect.* I. §. 16.

and Separation; in others, as Sand and Pot-aſh, Fuſion and Mixture; in ſome Dryneſs and Exſiccation, as in Clay; in others Softneſs and Pliability, as in Wax, *&c.* according to the Degree and Manner in which the Fire is applied. But for the Conduct to be obſerved in this Application certain general Rules are required. And firſt with regard to the kinds of Heat:

The kinds of Heat in Chemiſtry.

38. There are in Chemiſtry as many kinds of Heat as there are Mediums thro' which it may be conveyed, or Fuels that afford it.

39. For common uſe, Heat is conveyed either thro' Water, Aſhes, Sand, *&c.* or directly thro' the containing Veſſel.

Balneum Mariæ, *Sand-Heat,* &c.

40. When Heat is conveyed thro' Water it is called the *Balneum-Mariæ*, or Water-Heat; when thro' Aſhes, an Aſh-Heat; when thro' Sand, a Sand-Heat; and when thro' no intermediate Subſtance at all, a naked Fire.

41. Some Differences may be found in the Effects produced by theſe different Heats applied in the ſame Degree: but they have not perhaps been noted as they deſerve.

42. In ſeveral Bodies 'tis evident that dry and moiſt Heats have different Effects; as we find remarkably in the common culinary Operations of boiling, roaſting, baking, *&c.* And hence, where the Effects are required perfectly ſimilar, the ſame kinds as well as degrees of Heat are to be uſed.

The Degrees of Purity in Chemical Fires.

43. The pureſt Fire is that of Alcohol or perfectly pure Spirit of Wine; the next in Purity is that of diſtilled Oils; the next, that of Charcoal, or charred Turf; and the impureſt, that of Pit-Coal: But all theſe have nearly the ſame Effect, when received thro' the ſame kind of Medium.

IV.

The Degrees of Heat. 44. The laſt thing to be conſidered is, how to regulate and aſcertain the Degrees of Heat in Chemical Operations, ſo as to produce the Effects required in every Caſe.

Uncertain. 45. The common Directions of the Chemiſts about this Matter are full of Uncertainty; their firſt, ſecond, third, and fourth Degrees of Heat, meaning no preciſe Degrees meaſured by any Standard.

How to be regulated. 46. To reduce this Affair to the neceſſary Accuracy proper Thermometers might be employed, filled either with Oil or Quickſilver, and graduated from the freezing Point, or any other fixed Point of Cold, up to the Degree of boiling Quickſilver. Thus would come in their reſpective Places, (1.) the Degrees of Heat beſt ſuited to Vegetation, which might be ſerviceable in regulating the Temper of Green-Houſes. And this temperate Heat is fit for extracting the native Spirits of odoriferous Vegetables with Oil; as of Roſes, Jaſmin, *&c.* and again, for making the more curious Inſolations, *&c.* *The firſt Degree.*

The ſecond. 47. (2). The next Degree of Heat may be accounted that of the human Body in a healthy State, which is always greater than that of the ambient Air. But when the Body is dead, it receives the ſame Degree of Heat with the ambient Fluid. This ſecond Degree of Heat is adapted to vinous and acetous Fermentation, Putrefaction, Excluſion of the Chick; the finer Digeſtions, the making of Tinctures and Elixirs; and the Adepts have uſed it for the firſt Digeſtion of their Mercury, by carrying the including Veſſel conſtantly in their Pocket.

48. (3.) The third Degree of Heat in this Progreſſion may be that of boiling Water, when the Atmoſpere is in a middle State of Rarefaction. This Degree is required in the Diſtillation of ſimple and compound Waters, the eſſential Oils of Vegetables, and will coagulate or conſolidate the Serum, Blood, and other animal Juices, and conſequently deſtroy animals. *The third.*

49. (4.) A fourth Degree of Heat may be that wherein Quickſilver or Oil of Vitriol boils, diſtils, or becomes volatile. This Degree is ſuited to the melting of Lead, Tin, Biſmuth, *&c.* the ſubliming of Sal Ammoniac and Sulphur; the calcining of Antimony, *&c.* *The fourth.*

50. (5.) A fifth Degree of Heat may be that wherein Iron is kept in thin Fuſion. By this Degree all the other Metals are melted, *viz.* Gold, Silver, and Copper; Glaſs is made, and the unvitrifiable Stones calcined. *Fifth.*

51. (6.) The ſixth and higheſt Degree of Heat hitherto known, is that of the burning Lens, or the Concave Mirror of M. *Villette*, *Tſcirnhauſen*, and others. The Focus of theſe Glaſſes will even volatilize what is called the Metalline or Mercurial part of Gold, and vitrify the more terreſtrial. *Sixth.*

52. And thus much for regulating the Degrees of Heat to be employed in Chemical Operations. We muſt next conſider by what means the preceding Degrees of Heat may be excited and preſerved, as Occaſions require. *The Degrees of Heat, how raiſed and preſerved.*

53. (1). The Fuel muſt be choſen ſuitable to the Intention. The natural Sun in Summer ſuffices for Inſolations. A Spirit-Lamp may be made to give a moderate, or a conſiderably ſtrong Heat, according to the number of Wicks employed; and its Strength may be eaſily meaſured and adjuſted by the Thermometer.

54. (2.) The lighter Fuels, ſuch as Straw, Leaves, Twigs, &c. come next in order after Spirit of Wine. (3.) Then Oils, Wax, Roſin, Pitch, &c. And, (4.) Laſtly, ſolid Wood, Coals and Turf; all which may have their proper Furnaces, ſo as to be burnt in the requiſite Quantity and with the requiſite Fierceneſs or Slowneſs.

The greateſt Heat with Fuel. 55. To excite the greateſt Degree of Heat in a Furnace the Rule is, to uſe the denſeſt Fuel, in the largeſt Quantity, and with Bellows all round the Furnace, inceſſantly blown, and directed to the central Point of the Fire wherein the Matter to be acted upon is lodged. And in this manner may be procured a Degree of Heat ſufficient for any of the known Operations upon Metals, Minerals, Glaſs, &c. that require the ſtrongeſt culinary Fire *a)*.

V.

AXIOMS *and* CANONS, *for the better Knowledge and Regulation of Fire.*

We learn from the preceding Enquiry;

1. That the direct Senſes afford but little Information as to the real Nature and eſſential Properties, or *Form* of *Fire b)*.

2. That the *Form* of Heat and Fire is a certain bridled or reſtrained Motion, excited, maintained, and ſtruggling in the minute Parts of Bodies, and tending to throw them off at the Surface *c)*.

N. B. *If this* Form *be rightly diſcovered, then to introduce ſuch a Motion among the Parts of any Body,*

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a) If more be deſired upon this extenſive Subject, the Reader may conſult the Lord *Bacon*, Dr. *Hook*, Mr. *Boyle*, Mr. *Evelyn*, Dr. *Bohn*, M. *Homberg*, Dr. *Boerhaave*, and Dr. *Stahl*.

b) See above, §. 3, 4, 5, 6, 7, 33.

c) See §. 7, 8, 9, 10, 11, 26, 27, 28, 29, 32, 33, 34.

Body will be to introduce Heat; or, if the Nature of the Body be capable of it, Ignition or Inflammation.

3. That as the direct inflammable Matter in all Fuel is the Fat or Oil it contains *a*), the moſt oleaginous Fuel is the beſt or richeſt.

4. That Flame is the ſmall Parts of an inflammable or conſiderably unctuous Body, actually ſet on fire, or briſkly agitated and thrown off, with a certain vibrative Motion, at the Surface of that Body, into the open Air *b*).

5. That Flame cannot exiſt without Oil *a*). Whence it is that Aſhes, Sand, Glaſs, Stones, and Earths do not flame upon Ignition, but rather damp and extinguiſh Flame.

6. That as Oil is the only inflammable Subſtance in nature *a*), this may direct us to the means of preventing Conflagrations; *viz.* by uſing ſuch Materials in Building as contain little or no Oil. This Direction might be likewiſe extended to the making of incombuſtible Paper for valuable Books and Manuſcripts; new Materials for Hangings, Furniture, &c.

7. That as all Flame catches and exiſts only on the Surface of inflammable Bodies *c*); we are hence led to invent Methods of caſing, or otherwiſe defending, the Wood work of Ships and Buildings from Accidents by Fire.

8. That as the three capital kinds of *Fire* have a near relation, and may be very well reduced to one, for human Uſes, *viz.* the culinary kind *d*); Men may have reaſonable Hopes of performing conſiderable things by its means in

a) See above, §. 22, 23, 24, 25, 33, 34.

b) See above, §. 26, 27, 29, 33. 34.

c) See above, §. 33. 34.

d) See above, §. 13--20, 34, 36, &c.

imitation of Nature; as particularly in promoting and regulating Vegetation, the Ripening of Ores, *&c.* by artificial Heats.

9. That Fire and Flame are aboliſhed or extinguiſhed by Suffocation, or an Action contrary to Ventilation *a)*, as being deſtructive or preventive of that internal Commotion and Diſcharge of the oily Particles of the Fuel by means of the free Air, in which the nature of open and conſuming Fire and Flame conſiſts *b)*. Hence Fire and Flame are quenched by Water, or even by Spirit of Wine or Oil of Turpentine, if a live Coal or lighted Candle be ſuddenly plunged therein below the Surface of the Liquor. For the Degree of Heat which Water, Spirit of Wine, or Oil of Turpentine unfired, are capable of receiving, being much leſs than that of a burning Coal or Candle, the greater Heat is ſubdued by the leſs; juſt as Fire is quenched by boiling Water.

10. That Heat is Fire in a leſs Degree, and Fire only a greater Degree of Heat, on which Lucidity, and, if the Matter be unctuous, Inflammability *b)*, depend: as we ſee in hammering a Piece of Iron till it becomes red-hot; and in the firing of Wind-mills, or Coach-wheels, by their own violent Motion.

11. That Heat muſt aggregate and collect in a certain Proportion before it become cognizable to the Senſes, or produce any manifeſt Effects of Fire or Flame. Thus a Degree of Heat below that of the natural human Body is inſenſible, or paſſes for a Degree of Coldneſs; and the ordinary Motion of Wind-mills, Carriages, *&c.*

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a) See above, §. 26, 27, 29, 30, 31. See alſo *Axiom* 2 foregoing.

b) See above, *Exp.* III, IV, V, and VI.

produces no remarkable Heat; tho' when the Motion is greatly increaſed, or the Friction conſiderable, it ſoon excites Fire and Flame *a.)*

12. That all the Chemical Operations require a certain or determinate Heat, in order to their being performed to the greateſt Advantage; and that this Heat may be aſſigned and obtained, in every caſe, to the great Improvement of Chemiſtry *b)*.

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a) See above. §. 3, 4, 5, 6, 7.
b) See above, §. 44, 45.

LECTURE III.

CONTAINING

(1.) *The general Properties,* (2.) *Ingredients,* (3.) *Nature,* (4.) *Office and Uſe of the Atmoſphere.*

(5.) *The Changes therein*; (6.) *The Effects it produces on the Terreſtrial Globe, and* (7.) *In Chemical Operations.*

I.

The Subject.

1. WE are now to enquire into the Chemical Nature, Properties, Ingredients, Office and Uſe of the Atmoſphere.

The Atmoſphere, what.

2. By the *Atmoſphere* we underſtand that whole Maſs of rarefied Matter, or dry Fluid which ſurrounds the Globe of the Earth to a conſiderable Height.

Its Import to Chemiſtry.

3. To diſcover the Nature, or the Influences and Effects of this Fluid, is of the utmoſt Importance to Chemiſtry; it being the general Fluid wherein all Animals, Vegetables, and Minerals grow, wherein our Fires burn, and every Chemical Veſſel and Subject is included.

To be examined in three States.

4. We ſhall examine it as exiſting in three States, *viz.* (1.) As it is an intire Maſs that ſurrounds the whole Terraqueous Globe; (2.) As it conſiſts of diſſimilar Parts, whilſt it either lies open and remains one with the reſt, or elſe is ſeparated therefrom by being included in our Glaſſes or Veſſels; and (3.) As it is united with, or fixed in Bodies. And from this Examination of the

Parts of this general Fluid in different places we may infer the nature of the whole.

EXPERIMENT I.

That different Effluvia mix and form Clouds, or unite in the Atmoſphere.

5. We unſtopped a Bottle of ſtrong Spirit of Sea-Salt, and another of volatile Spirit of Sal Ammoniac; and ſetting the Bottles near each other, the Vapours inſenſibly ariſing from them met, and formed themſelves into a very groſs viſible Fume or actual Cloud, that continued for ſome time, but afterwards diſappeared, or mixed more intimately with the Air of the Room.

That the Atmoſphere receives Vapours.

6. One of the Liquors here employed is an acid Spirit, and the other an alkaline one, which being mixed form a Species of neutral Salt or Sal Ammoniac. And as their Fumes are no other than fine Parts of the Liquors themſelves, that ſtill retain their Nature, they conſtitute this Kind of neutral Salt in the Air.

7. That ſomething of the ſame kind naturally happens in the Atmoſphere appears from hence, that all Vegetables produce a kind of volatile Salt by Putrefaction; that the volatile Salts of putrefying animal Subſtances, no leſs than the former, naturally go up into the Air, which contains likewiſe ſome Proportion of Sea-Salt raiſed from the Earth and Ocean: ſo that if theſe Particles meet they will neceſſarily make a kind of Ebullition, and unite into a neutral Subſtance, in the Atmoſphere; which may hence abound with a variety of acid, alkaline, and neutral Salts, the Signs whereof are evidently diſcovered by the Changes they produce in the Colours of different Bodies.

8. This Experiment therefore may ſhew to the Eye ſomewhat of the phyſical manner wherein Clouds and Meteors are generated in the Atmoſphere, and teach us that Salts naturally abound therein: whence again we have the phyſical Reaſon of many Effects produced by the atmoſpherical Air, in the animal, vegetable, and mineral Kingdoms, and in many Chemical Operations.

9. That the Atmoſphere not only ſupports Vapours or Effluvia raiſed into it from the Earth, but alſo preſſes upon terreſtrial Bodies by its Weight, appears from many Pneumatical Experiments; of which kind we need only produce two or three for the preſent.

EXPERIMENT II.

That the Atmoſphere preſſes upon Bodies by its Weight.

The Preſſure of the Air.

10. This was made ſenſible to the Hand applied cloſe on the top of a hollow metallic Cylinder or Ring, about two Inches in Diameter, ſet upon the Air-Pump; for the Air being drawn out of the Cavity underneath, the Hand was remarkably preſſed inwards, and felt a conſiderable Weight.

11. The Effect was likewiſe ſhewn in a different manner to the Eye, by the breaking of a piece of flat Glaſs applied cloſe to the top of the ſame metallic Ring: for the Air being drawn away from below, the Glaſs was immediately cruſhed to pieces and fell inwards, with a loud Noiſe and a conſiderable Force.

The Air's Elaſticity.

12. Beſides this Weight or Preſſure the Air or Atmoſphere has likewiſe an elaſtic Force which is no leſs conſiderable; as appears by many Examples, and particularly by the following.

EXPERIMENT III.

That Air is elaſtic, or capable of forcing, diſtending, or ſqueezing Bodies by its Spring.

13. We included a little Air in a Bladder, ſo as to leave it almoſt flaccid, and tying the Neck cloſe put it into a Receiver, out of which we then exhauſted the Air (but not out of the Bladder;) whereupon the Bladder immediately ſwelled and appeared as if full blown: but upon readmitting the external Air the Bladder was preſently ſqueez'd up, or contracted to its former Dimenſions.

14. The ſecond and third Experiment therefore ſhew that the Air or Atmoſphere, both in its natural unconfined State, and when certain Portions thereof are included in Veſſels, continually exerciſes a gravitating and an elaſtic Power, capable of producing many Effects; as continually preſſing, by its Weight and Spring, all the Bodies we know. It perpetually preſſes upon the Surface of the Earth, with a Weight equal to that of a Column of Quickſilver whoſe Baſis is that Surface, and whoſe Height is about 29 Inches; as manifeſtly appears by the Barometer.

15. Hence the Atmoſphere will inſinuate itſelf into the open Pores on the Surfaces of all Bodies, capable of receiving its component Particles. So that the Pores of many Subſtances, though to our Senſes they appear Vacuities, are full of common Air; which thus produces the proper Effects of Air, in Diſtillations and many other chemical Operations.

16. The Atmoſphere alſo, as a Fluid, muſt by the Laws of *Hydroſtatics* preſs Bodies equally every way, and the internal Air of Bodies acting within, whilſt the external Air acts without, nu-

merous phyſical Effects are hence produced in that great Laboratory, the Earth; where Bodies are by natural Powers and Agents diſſolved, putrefied, changed, and carried off into that grand Repoſitory the Air.

The Effects and compounded Nature of the Atmoſphere.

17. And tho' the Atmoſphere itſelf be inviſible, yet we cannot but be ſenſible of the Effects it produces, ſeeing they are by means of proper Contrivances and Obſervation, made perceptible even by the Senſes, as in the preceding Experiments. And thus, tho' the Atmoſphere be a rarefied and moveable Fluid, ſo that Bodies eaſily paſs thro' it, yet broad Surfaces are greatly reſiſted by it. And hence its Force, as a reſiſting Fluid, becomes manifeſt in high Winds, by driving and diſſipating the Clouds, and all kinds of Vapours and Exhalations; which are thus mixed in with the Maſs of the Air, ſo as to form a heterogeneous Fluid, or Chaos of infinite Materials.

EXPERIMENT IV.

The Conſtruction, Nature, and Uſe of the common Thermometer.

Thermometers explained.

18. (1.) The common Thermometers are Glaſs-Tubes fill'd with tinged Spirit of Wine, and graduated, ſo as to ſhew, by the riſing or falling of the Liquor, the Degrees of Heat to which it is expoſed.

19. (2.) Spirit of Wine is choſen for this Purpoſe, becauſe of all known Fluids it is the moſt rarefiable with Heat, next to the Atmoſphere itſelf. Denſer Fluids might be employed, but the Diviſions would then be leſs; and Water is unfit for this Purpoſe, as freezing with Cold.

20. (3.) Theſe Thermometers are the exacteſt Inſtruments hitherto known for meaſuring the Degrees of Heat; being filled either with Alcohol,

Brandy, Oil, or Quickſilver, according to the ſeveral Purpoſes for which they are deſigned a).

21. (4.) The common Thermometer ſhews the Warmth of the Air; and that it always contains ſome Degree of Fire or Heat, more or leſs: for Spirit of Wine has never been found to freeze or congeal with any Weather, in any Climate; but riſes and falls in the Tube as the Weather is more or leſs hot; with regard to which alſo the Atmoſphere frequently varies.

Experiment V.

To determine the Proportion of Water contained in an aſſigned Portion of the Atmoſphere.

Water in the Air.

22. Having, by means of the Air-Pump and an exact Pair of Scales, found the Weight of a certain Quantity of Air contained in a large Glaſs Veſſel, we included therein a known Weight of well dried Potential Cautery (whoſe Property is powerfully to attract the Moiſture of the Air;) and kept this Veſſel cloſe ſtopped for ſeveral Hours, during which time the Potential Cautery was grown wet: in this ſtate we weighed it again and found a conſiderable Increaſe; which muſt be owing either to the Water attracted out of the Air in the Glaſs, or to a Condenſation of the Air itſelf into an aqueous Fluid: for ſuch a Fluid might now by Diſtillation be obtained from the Matter thus run *per deliquium* b).

23. There is ſome room to ſuſpect that, if this Experiment were made in Perfection, a Weight of Water, almoſt equal to that of the Air included in the Veſſel, might be thus obtained; which would prove a very extraordinary Diſcovery, and ſhew

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a) See *Lect.* II. §. 46.

b) The Experiment was not made with all the requiſite Exactneſs.

ſhew what ſome have endeavoured to prove, that the Matter of common Air is little more than Water *a*).

24. That much Water muſt needs be contained in the Air appears evident from the Quantity daily exhaled by the Sun, from the Ocean, the Rivers, and the whole animal, vegetable, and mineral Kingdoms. And as the Water ſo raiſed into the Atmoſphere muſt neceſſarily mix and join with the ſaline and other Particles it there meets with, and is capable of diſſolving; hence the Water of all our Springs, Rivers, and the Ocean itſelf is impregnated with numberleſs Matters, that little appear in Water. And poſſibly to give the animating or vivifying Spirit to Water, it is phyſically neceſſary that it ſhould be perpetually refined or refreſhed by this Kind of Diſtillation, or recruited and new impregnated with the Effluvia or fine Particles of all the Bodies floating in the Atmoſphere; after the ſame Manner as a ſkilful Operator, to give his diſtilled Waters the finer Impregnation, ſuſpends a proper Mixture of Ingredients in the Head of his Still.

EXPERIMENT VI.

That a Refreſhment or Renewal of Air is neceſſary to Life.

Freſh Air required in Reſpiration.

25. If Animals or Plants be long continued in the ſame cloſe, unchanged, or unrefreſhed Air, they will languiſh and expire, much after the ſame manner as Fire would do, by a Kind of Suffocation *b*).

26. Hence it appears that the Air, which has once ſerved for the Reſpiration either of an Animal or Vegetable, is unfitted for the ſame Office again,

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a) See the Lord *Bacon*'s Natural Hiſtory of Winds, *paſſim*.

b) See *Lect.* II. §. 29. & alibi *paſſim*.

again, till it be recruited, as it ſeems to be, by mixing with the open atmoſpherical Air. Every Man is computed thus to deſpoil a Gallon of Air in a Minute; whence, if the Number of Animals and Vegetables on Earth be conſider'd, it ſhould ſeem that the whole Atmoſphere muſt in time be deſpoiled, unleſs ſome natural means were uſed to prevent it. Indeed, on weighing the matter attentively, one might ſuſpect that the Particles of numberleſs Materials, fermenting * together in the Atmoſphere, produce a certain *Spirit*, or fine vivifying Subſtance, that thus renovates and invigorates the whole Maſs, and renders it again fit for Reſpiration and the Suſtentation of all natural Bodies. And hence perhaps it is that no ill Effects are uſually felt from that immenſe Quantity of groſs Smoak continually diſcharged into the Atmoſpheres of large Cities. All Bodies ſuffer a kind of Tranſmutation, and may, by the eſtabliſhed Courſe of Nature, go the ſame rounds again. And hence alſo it is no wonder that Air, when ſo richly impregnated with Water, Soot, Smoak, Salts, Oils, Kitchen-Exhalations, *&c.* ſhould prove in ſome degree nutrimental.

EXPERIMENT VII.

That looſe Air is contained in Fluids.

27. We put Water, Small-Beer, and Brandy ſeverally into an Air-Pump Receiver, and exhauſting the Air obſerved numerous Bubbles to ariſe and eſcape from each Liquor, burſting upon its Surface. *Air in liquors.*

28. And in like manner is Air diſcharged from Liquors by boiling them over the Fire: This is practiſed upon Water, in order to make

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* See *Lect.* VII. *paſſim.*

it afford Ice without Blebs or Bubbles; and again upon Oil deſigned for *Thermometers*, &c. But ſuch Liquors as have been thus diſcharged of their looſe Air, will be found to recover it again by ſtanding open; as if looſe Air were a natural Ingredient in Liquor.

EXPERIMENT VIII.

That the external Air may promote Solution.

The Air may promote Solution.

29. We ſet ſome Spirit of Sal Ammoniac and Copper-Filings *in vacuo*, and compared this with a like Parcel ſtanding for the ſame time in the open Air: that *in vacuo* had not coloured its Menſtruum, whilſt that in the open Air afforded a rich blue Tincture. Hence it appears that the free Acceſs of the external Air may promote Solution in ſome Caſes; where it ſeems to act by increaſing the Motion or Action of the Menſtruum.

EXPERIMENT IX.

That the external Air does not promote Solution in all Caſes.

Yet in ſome Caſes only.

30. Upon two Drams of whole Crab's Eyes we poured *in vacuo* two Ounces of diſtilled Vinegar, having firſt boiled it to get out the Air. A great Ebullition was immediately produced, the Gage ſunk, and Air was generated.

31. Upon comparing this with the ſame Experiment made in the open Air, we found that the Ebullition was much greater *in vacuo* than in the open Air.

32. Hence we learn that Air may be generated upon the mixture of certain Bodies, where it did not appear before.

33. But Experiments of this Kind muſt be made with Caution; the Quantity of Air thus generated in ſome Caſes being able to raiſe the Receiver, and throw it to a conſiderable Diſtance.

34. There is wanting an Account of all the Mixtures that will produce Air in ſo violent a Degree; among them may be reckon'd *Oil of Vitriol* with *Oil of Tartar per deliquium*, *Aqua-Fortis* with *Iron Filings*, *Spirit of Nitre* with *Oil of Caraway*, *&c.*

35. And thus Air may be generated betwixt Solids and Fluids, and betwixt Fluids and Fluids, by bare Mixture. The following Experiment will ſhew that Air may be extricated out of Solids, and that it makes a conſtituent Part thereof.

EXPERIMENT X.

That Air enters the Compoſition of Solid Bodies.

Air in Solids.

36. We put a Piece of hard Tallow into an Iron Retort with a long Neck; then laying the large End of the Retort in a naked Fire, the ſmall one being plunged into Water, we diſtilled in the uſual Manner, and obſerved that large Bubbles of Air continually roſe and diſcharged themſelves thro' the Water into the Air of the Room. At length ceaſing the Operation, and collecting all the viſible Matter either left behind or come over into the Water, we found a very conſiderable Loſs of Weight, owing to the Air having been ſeparated or forced by the ſtrong Heat from the reſt of the Tallow *.

37. If it be objected that the Loſs of Weight might, in great Meaſure, be owing to the Iron of the Retort, which when hot has the Property of drinking in Oil or Tallow; it may be obſerved,

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* The Experiment was not made with requiſite Care and Caution.

ved (1) That the Effect is nearly the ſame when an Iron Retort is employed that has been uſed for the ſame Operation before; (2) That the Experiment anſwers proportionably when made in Glaſs; (3) That other Bodies beſides Tallow, particularly Hartſhorn, Bone, Tartar, &c. yield plenty of Air, when treated in the ſame manner; (4) As there is ſo large a Quantity of Air-Bubbles diſcharged in the Operation, and as Air is proved to be a ponderous Body *a)*, the Loſs of Weight may be fairly attributed to the eſcape of the Air. But (5) a proper Gage may be contrived to determine the exact Proportion of the Air thus ſeparated, with reſpect to the original Matter or Subject employed *b*).

38. This Experiment is of great Importance in Natural Philoſophy and Chemiſtry. When fully verified and duly proſecuted it may ſhew (1) that all natural Bodies conſiſt of a very large Proportion of Air, as one Part of their original Compoſition; (2) That Air is neceſſarily required to the Formation and Growth of Animals, Vegetables and Minerals; (3) That when Bodies are diſſolved or reſolved a great Part of them turns into Air again; as when a Candle is burnt or Fuel conſumed; or as when Vegetables, Animals and Minerals ferment, putrefy or corrupt; or as when Bodies are chemically analyſed or treated by Heat.

39. (4) That the Matter which in the Diſtillation of Hartſhorn, Tartar, and many other things explodes and puffs thro' the Luting, or ſometimes, when confin'd, burſts the Glaſſes or Veſſels, is the Air ſet free by the Heat.

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a) See above, *Exp.* II.

b) See Mr. *Hale's Vegetable Statics*, under the Analyſis of the Air.

40. (5) That the Air thus naturally condenſed, confined, and intermix'd as a conſtituent Part in Bodies, has a great Share in their Diſſolution; for being violently rarified it breaks the parts in pieces and flies off.

41. (6) But leaving the Experiment to be further verified, and made general, if capable thereof, we ſhall anticipate no more, but proceed to reap the Fruits of the preſent Enquiry.

II

AXIOMS *and* CANONS *derived from the Enquiry.*

1. We learn from the preceding Enquiry that the Atmoſphere, conſidered as a Whole, and again as conſiſting of an infinite Number of Ingredients, is the Phyſical Cauſe of numerous Effects, not only in the Air itſelf, but likewiſe upon the Surface of the Earth, in the ſubterraneous Regions, in the Exerciſe of numerous Arts, and particularly in Chemical Operations *a*).

2. That it is the phyſical Office and Uſe of the Atmoſphere to aſſiſt in raiſing the Vapours and Exhalations of the Earth *b*), and to ſerve as a general Matrix for them *c*), wherein they are all blended together and fermented, or ſome way changed in their Nature, ſo as to perform new Offices, or recruit the vegetable, animal, and mineral Kingdoms, when ſuch enriched Vapours fall back again in Rain or Dew to the Earth *d*).

3. That it is the Nature of Air to inſinuate itſelf into Fluids *e*), unite and fix in Solids, ſo as

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a) See above, *Exp.* II. III. IV. V. VI. VII. VIII. IX. X.
b) See *Exp.* I.
c) See *Lect.* I §. 16.
d) See §. 25, 26. & *alibi paſſim.*
e) §. 27, 28.

naturally to make a conſtituent Part of both *a*).

4. Hence may be conceived, in general, how all the Changes happen in this great Chaos the Atmoſphere; *viz.* according as floating Particles of different Kinds chance to meet, ſo as to form conſiderable Aggregates or Collections; and according as theſe are favoured by the requiſite Degrees of Heat, Cold, Dryneſs or Moiſture. So, for example, a Cloud of nitrous Spirit meeting with a Cloud of oily Particles might ſuddenly produce Corruſcations, as in the mixing of Spirit of Nitre and an eſſential Oil *b*). And in this manner may the Generation and Phænomena of all the Meteors be chemically explained. And thus the Occurſions of various Parts of different Bodies in the Atmoſphere may be the Cauſe of the Meteors, fiery Winds, Exploſions, Thunder, Lightning, the Aurora Borealis, and other Phænomena, which we can imitate by certain Mixtures, in the way of Philoſophical Chemiſtry *c*).

5. That the Atmoſphere is an univerſal Inſtrument, in the Hands both of Nature and of Art, for producing Effects, whether on the Surface of the Globe, in the Bowels of the Earth, in the Air itſelf, in the Laboratory, or in other human Works *d*). Thus it cauſes Fire to burn, and Bellows are but Engines to convey it thereto.

6. That as Air deſcends, and acts more forcibly in the ſubterraneous Regions, on Account both of its greater Denſity there, and of the ſubterraneous

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a) §. 27, 28, 36, 37, 38.

b) See *Exp.* I.

c) See Mr. *Lemery*'s Philoſophical and Chemical Explanation of Subterraneous Fires, Earthquakes, Hurricanes, Thunder and Lightning, in the *French* Memoirs, *Anno* 1700,

d) See the whole *Lecture paſſim*. See alſo *Lect.* I. *paſſim*.

Heat; hence Vulcanos and more violent Fires may happen there than upon the Earth's Surface *a*). And poſſibly this greater Heat and Power of the Air below is neceſſary to the Production of Minerals and Metals *b*).

7. Hence we may learn the phyſical Cauſe why in the open Air diſtilled aromatick Oils loſe their native Spirit, grow thick, and terebinthinate; why Wines grow flat or loſe their Briſkneſs; why pale volatile urinous Spirits grow red; why Mineral Waters loſe their Virtue; and how Air has in all reſpects a powerful Influence upon Liquors; as being a dry Fluid in briſk Motion, whereby it eaſily lays hold of and carries off all the moſt ſubtile and volatile Parts of Fluids, leaving the groſſer behind, and thus changes the Texture, Colour, and Conſiſtence thereof *c*).

8. That the Atmoſphere is, perhaps, the moſt compounded and diſſimilar Maſs in Nature; conſiſting of an elaſtic Part, and the Vapours and Exhalations ariſing from all the ſolid and fluid Bodies of the Globe, Salts, Oils, Minerals, Metals, *&c. d*).

9. That the Air is the Cauſe of numerous Effects, ill aſcribed to other Cauſes by the ancient Chemiſts, who for want of the Air-Pump and other Contrivances, were ignorant of the genuine Properties and Effects of the Air *e*).

10. That the component Parts of the Atmoſphere are coarſer than thoſe of Fire. For the

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a) See *Lect*. II.

b) See above, *Exp*. X. See alſo the *Lecture* on Metallurgy hereafter.

c) See *Exp*. I. VI. IX. & §. 18.

d) See *Exp*. I. *&c*.

e) See *Exp*. VIII. IX. X.

component Parts of the Atmoſphere will not paſs thro' Glaſs *a*), Stones, Metals, *&c.* as Fire does. Alſo Water, Lixiviums, Oils, *&c.* paſs where Air cannot; as we ſee in Bladders, Wet-Leather of the Air-Pump, *&c.* Hence the Air may be artificially excluded from many Bodies. *b*).

11. That the Atmoſphere is continually at work upon all the Bodies Subject to its Power, in the way of a Menſtruum; whence Iron ſtanding in the open Air is corroded; imperfect Glaſs diſſolved; Salts and Sugars run into Liquor; and the Bodies of Animals, Vegetables and Minerals prey'd upon *c*).

12. That there is a continual Reciprocation betwixt the Earth and the Atmoſphere; they mutually diſtilling, as it were, or throwing off Matters from one into the other. Thus the Earth, by the Sun's Heat, ſublimes ſome Parts of all things into the Atmoſphere, and the Atmoſphere again precipitates them to the Earth *d*).

13. That the different Succeſs of Chemical Operations may be greatly owing to the particular Vapours or Effluvia floating in the Laboratory where ſuch Operations are performed *e*). Thus if Salt of Tartar be run *per deliquium*, where Vinegar is diſtilling, it becomes regenerated Tartar; a thing very different from the intended Oil.

14. As Air always adheres to the Surfaces of Bodies, and as the Surfaces of Bodies are enlarged by pulverizing them *f*); when we would exclude

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a) See *Exp.* II, III. VII. VIII. IX.

b) See *Exp.* II. III. VII. VIII. IX.

c) See *Exp.* I. II. V. VI. VII. VIII. IX. See alſo below, *Ax.* 20.

d) See *Exp.* I. & *Lect.* I. *paſſim.*

e) See *Exp.* I.

f) See *Exp.* II.

Air in Chemical Operations, the Subject ſhould not be pulverized.

15. That the open Air has a powerful Efficacy in many Chemical Operations, eſpecially in Mixture *a*), where it often acts mechanically by its Weight and Motion; as in the mixing of Oil of Turpentine with Salt of Tartar, which does not ſucceed *in vacuo*, or in high mountainous Places.

16. That the Acceſs of Air is not neceſſary to certain Fermentations, or Ebullitions, and Solutions; ſome of them proving more violent *in vacuo*, than in the open Air *b*).

17. That no Degree of Cold, or Condenſation, has hitherto been able to deprive Air of its Fluidity, or render it conſiſtent *c*). If there were ſuch a Power exerted in Nature, it would deſtroy all Animals and Vegetables, and perhaps ſtop the Growth of Minerals *d*).

18. By comparing the preſent Enquiry with the preceding, it appears that Fire cannot ſeparate Oil from Bodies, without the Admiſſion of the free Air. Whence in the roaſting of ſulphureous Ores, or obtaining of white Aſhes from Bones or Vegetables, we are directed to uſe an open Air, as well as a naked Fire.

19. That the Air is in a Kind of perpetual Motion *e*). Whence it performs all thoſe natural Offices, that cannot be performed in a *Vacuum*. Thus leaven'd Paſte will not ferment or riſe, nor Wine work, nor Fleſh putrefy, nor Fruit corrupt, after the uſual manner, when placed *in vacuo*.

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a) See *Exp.* VIII.
b) See *Exp.* IX.
c) See *Exp.* IV.
d) See *Exp.* VI. & X.
e) See *Exp.* I. & IV. See alſo *Ax.* 12. & 17.

20. That as all kinds of Particles naturally float in the Air a), the Air may on this Account act as an univerſal Menſtruum, and in time diſſolve any Body expoſed to its Action; becauſe, in tract of Time, the Particles capable of diſſolving it muſt neceſſarily come at it b).

21. That many Arts may be aſſiſted, or carried on to better Advantage in ſome places than in others, by the means of certain Particles floating in the Air of one Place more than another. Thus 'tis ſaid that the Scarlet Dye is better ſtruck at *Leyden*, than in other Places of *Holland*, where the Water and Atmoſphere are not ſo impregnated with the Effluvia, Exhalations, or fine Particles of the Dye c).

23. Hence alſo we are directed to chuſe proper Seats for Health, and Habitation, as well as for Operations and the Exerciſe of Arts d).

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a) See *Exp.* I. & *alibi paſſim.*

b) See *Ax.* II.

c) See *Exp.* I. & *alibi paſſim.*

d) There are various Methods of trying the Wholeſomeneſs or Unwholeſomeneſs of Airs and Places; as by finding their Degree of Moiſture ſeveral ways; by the Changes of Colour produced in white Linen, or ſtained Paper, left out in the Air; by expoſing Copper-Plates to ſhew the Colour of the Vitriol thereby made; and many other Expedients might be contriv'd for that Purpoſe. [See Mr. *Boyle*'s Natural Hiſtory of the Air.]

LECTURE IV.

CONTAINING

The Solid or Earthy Matters of the Terreſtrial Globe claſſed, and examined, under (1.) *Garden Earths*; (2.) *Bolar Earths*; (3.) *Saline Earths*; (4.) *Sulphureous Earths*; (5.) *Stony Earths*; *and*, (6.) *Metallic Earths.*

1. WE now come to enquire into the ſolid or earthy Contents of the Globe; more particularly into the Parts concerned in Vegetation. *The Subject.*

2. We ſhall begin with the Earth's Surface, and deſcend down gradually, ſo far as Men have hitherto dug.

3. The Earth's Surface is generally found covered with Verdure, or a Vegetable Coat, and in ſome Places with Sand, Duſt, or Mud. *The Upper Coat of the Earth.*

4. Under this ſuperficial Coat there uſually lies a Bed of Mould, or Underturf-Earth, of different Depths, from one Foot to two, three, or more, in different Places. (1.) This Mould, or Underturf-Earth, is the proper Matrix of Vegetables, and will come to be firſt examined in Order.

5. We ſhall next proceed to the other Species of Earths that lie below, *viz.* (2.) the Bolar; (3.) the Saline; (4.) the Sulphureous; (5.) the Stony; and (6) the Metallic. For under theſe *The Species of Earths.*

ſix general Claſſes, we apprehend, may all the earthy or ſolid Matters of the Globe be ranged.

6. It will therefore be our Endeavour to give a general Example of the Method of treating every Species, ſo as to diſcover their Natures, Offices, and Uſes.

EXPERIMENT I.

The farther Analyſis of Garden-Mould or Underturf-Earth by Water a).

Mould analyſed by Water.

7. (1.) We took four Pounds of freſh, black and crumbly Garden-Mould, that was eſteemed the beſt ſort, and had lain, for a Year, expoſed to the Atmoſphere, without being exhauſted in Vegetation.

(2.) This Mould we elixated in fair and freſh boiling Water, till all that was capable of diſſolving therein was got out or extracted by the Water.

(3.) Having thus obtained a Lixivium or Solution of our Subject, we filtred it thro' thick doubled Paper, in order to have it tranſparent, and at leaſt free from any groſs terreſtrial Parts, that might otherwiſe lodge therein.

(4.) This Solution, therefore, contains all the Parts of the Subject that are ſoluble in boiling Water *b*).

(5.) To bring theſe Parts nearer together, that they might manifeſt themſelves to the Senſes, and particularly to the Taſte, we exhaled away the more aqueous Fluid in the Form of Vapour.

(6.) Then comparing the concentrated Solution, with a Portion of the former that re-

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a) See *Lect.* I. *Exp.* I.

b) See *Lect.* I. *Exp.* I.

mained unevaporated, we found it taſte manifeſtly ſtronger or more ſaline.

(7.) To gain a fuller Information, we evaporated a Portion ſtill higher, and ſet it to cryſtallize, if any Salt would ſhoot a).

(8.) To a Part of the filtred Solution we added Syrup of Violets, *&c.* to diſcover whether the Solution was acid, alkaline, or neutral; and found it rather the latter b).

(9.) We waſhed the remaining terreſtrial Matter in ſeveral Waters, every time decanting the upper muddy Liquor, after a little ſtanding, in order to procure the pure Sand contained in the Mould; and found the Sand to be a large Proportion of the whole.

8. This Experiment, or rather Combination of Experiments, ſhews us a Method of reſolving the matrix Earth of Vegetables into the conſtituent Parts thereof, without altering their natural Form and Properties. Whence it ſhould ſeem that a true Judgment might be formed of Moulds, both in general and particular, ſo far as this Information reaches, and a Rule be obtained for their artificial Mixture or Compoſition. Thus we find the Mould under Examination contains a certain Proportion of fine Earth, capable of being ſuſpended in Water; much more of a groſſer heavier Part that readily ſinks in Water; perhaps a little neutral Salt; and a large Proportion of Sand. Hence if this Mould had come from the Iſland *Ceylon*, for inſtance, having there ſerved for the Growth of Cinamon, we might be directed by this Analyſis to make or mix up a Mould that ſhould reſemble it, with a View to produce Cinamon

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a) The Succeſs was not carefully noted.

b) See the Method of examining *Mineral Waters*, in the following *Lecture*.

in *England*. But to make the Experiment ſucceſsful, no leſs Regard muſt be had to the State and Ingredients of the Atmoſphere, than to the State and Ingredients of the Soil *a*).

9. To render the preſent Experiment more inſtructive and uſeful, for diſcovering the Principle of Vegetation, and the Nature of Earths and Plants, it were proper to compare it with a ſimilar Analyſis of certain vegetable Subjects. Thus by bruiſing a tender Plant, elixating all its ſoluble Parts with warm Water, exhaling the ſuperfluous Moiſture, and ſetting the Remainder to cryſtallize, we obtain the native ſaline part of the Plant, in the form of a ſolid Salt, which appears either of the tartareous or nitrous kind, according to the Nature of the Plant *b*).

10. Tho' any alkaline Plant, as Creſſes, were watered in its Growth with a Solution of Nitre, which upon Diſtillation affords much acid Spirit, the Plant would ſtill prove alkaline: and the ſame holds of every Plant and Salt hitherto tried *c*). Whence there appears to be in Plants a Power of changing any other Salt into their own. And hence we find, upon Experience, that Compoſts abounding in Sea-Salt, Nitre, or urinous Salts, all agree to promote Vegetation.

11. But as there may be certain more fixed Parts naturally contained in Mould, than will diſſolve in boiling Water; and as theſe Parts may poſſibly be looſened, digeſted, and rendered capable of aſcending into Vegetables, by the long-

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a) See *Lect.* III.

b) See M. *Homberg* on the Nature of Vegetable Salts. *Memoir. de l'Acad. An.* 1699.

c) I could wiſh the Experiment were tried with Sugar, Alum, Pot-Aſh, &c. both in Alkaline and acid Vegetables. But Care ſhould be taken not to uſe too much of the Salts, which in that Caſe would deſtroy the Nature of the Mould.

long-continued Action of the Sun and Atmoſphere; it may be proper to try a more powerful Analyſis of the ſame Subject.

EXPERIMENT II.

The Analyſis of Garden Mould by Fire.

12. Having weighed two Pounds of the ſame kind of Virgin-Mould as was uſed in the preceding Experiment, we put it into an earthen Retort, and committed it to a naked Fire, working by ſlow Degrees of Heat into a Glaſs-Receiver; and at laſt keeping the Retort ignited for ſome time. There came over (1.) a Water; (2.) an Oil; and (3.) a volatile Spirit almoſt like Spirit of Hartſhorn, or as if the Subject had been animal *; and (4.) there remained behind a dry *Caput mortuum*, or apparently fixed and inert Earth. *By Fire.*

13. We elixated Part of the *Caput mortuum*, and then dried it; by Triture we reduced another Part into one ſimilar, homogeneous Powder; with a deſign to put each Parcel into a ſeparate Pot, and expoſe them to the open Air, for a Year, to try whether they would then prove fertile.

14. It appears by this Experiment, that our Garden-Mould was of a Vegetable or Animal Nature, in reſpect of the Salts or Juices it contained; and only Mineral, with regard to its fixed Matter. In both which reſpects it greatly reſembles the natural Compoſition of Animals and Vegetables. And hence we ſee the phyſical Reaſon, why animal and vegetable Subſtances

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* If it be ſuppoſed, that the Compoſt, which might have been uſed to this Mould, was not ſufficiently rotted or changed, ſo as ſtill to retain its own vegetable or animal Nature; let the Experiment be repeated with Earth, which has been known to have lain ſeveral Years fallow.

are proper Compoſts for Land. If we were to enquire how Mould comes to be of this Nature, it might in good Meaſure appear from our former Doctrine of the natural Contents of the Atmoſphere; which being animal and vegetable, as well as mineral, continually fall upon the Surface of the Earth. And hence Gardeners find a manifeſt Difference between the Soil of *London* and that of open Country Places, on Account of the Quantity of Smoke daily precipitated out of the Air upon the Gardens of *London*. And the like is to be underſtood of other Cities and Countries reſpectively.

15. By comparing the preſent Proceſs with the ſame performed upon a vegetable, an animal, and a mineral Subſtance; it appears that one ſimple *fixed Earth* is the Baſis of all animal, vegetable, mineral, and earthy Matters; or the true *Stamen*, Support, and Skeleton of Fleſh, Bone, Wood, Metals, and Earths, *&c.* being in itſelf of a fixed unalterable Nature.

16. We next proceed to *Bolar Earths*, which ſeem diviſible into two Species, according as they are more or leſs tenacious; in which view *Loam* and *Clay* may repreſent them all. And even theſe two ſeem only to differ in reſpect of the Fineneſs or Coarſeneſs of their component Parts, which renders them more or leſs tenacious, clinging, or adheſive.

EXPERIMENT III.

That Fineneſs of Parts in Earths may give Coheſion, Strength, and Solidity.

Loam made into Clay.

17. (1.) We mixed common Loam into a Maſs with Water, and then dry'd it; to ſhew that, compared with Clay, it would eaſily break, crumble, and fall into Powder. But (2.) beating

ſome Loam fine in a Mortar, and mixing it well with Water, it clung like Clay; and when dry'd, adhered much more tenaciouſly than before.

18. This Experiment not only ſhews that Loam and Clay, or all the Bolar Earths, are nearly the ſame thing, when their component Parts, or gravelly and ſandy Matters, are reduced to the ſame Degree of Fineneſs; but alſo ſupplies us with a Rule for the Improvement of Pottery, and the Imitation of *China* Ware. This Rule is to grind, or beat, the Earths employed, to an extreme Degree of Fineneſs: and accordingly Porcellane has been imitated in *Europe*, by Tobacco Pipe Clay and other Earths exceedingly fine ground, mixed into a Paſte with Water, and properly dried or baked. *Pottery hence improveable.*

19. The ſame Experiment may likewiſe inform us how Rocks are often produced, of different Degrees of Hardneſs, according to the different Fineneſs of the terreſtrial Particles depoſited upon any Eminence, or Declivity, as waſhed down by the Waters. *Farther Uſes of the Experiment.*

20. We recommend it to future Examination how far this mechanical Tenuity of Parts may reach, in cauſing Strength and Hardneſs in Bodies: and whether thoſe two Properties are not different in Glaſs, Cryſtal, Diamonds, &c. on Account of the different Fineneſs of their Parts. *.

21. Under this Tribe of Bolar Earths we rank all the hungry Garden-Earths, all the ſandy Field-Earths, all the Clay or Marly Earths, and all the Mixtures thereof. *Bolar Earths what.*

22. We next proceed to Saline Earths; by which are meant all thoſe wherein any Quantity of Acid, Alkaline, or Neutral Salt is evidently contained. *Saline Earths.*

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* See Mr. *Boyle* on Gems.

23. If ſtrict Examination were made, perhaps no Earth would be found without ſome Proportion of Salt; which has pretty generally been thought the Principle that holds all Earths together. And there appears ſome Reaſon for the Opinion, as we endeavoured to ſhew by the following Experiment.

EXPERIMENT IV.

That a Saline Matter may give Tenacity and Firmneſs to Earth.

Quick-lime deprived of its Salt.

24. (1.) We ſlaked Quick-lime with a ſufficient Quantity of Water to bring it into a Kind of Paſte; (2.) Then ſuffered the ſuperfluous Moiſture to exhale gradually: Upon which, (3.) the Lime acquired a ſtony Hardneſs. (4.) We next poured a much larger Quantity of Water upon another Parcel of Quick-lime, than ſufficed to make it into a Paſte; then decanted the Water, which taſted manifeſtly ſaline. (5.) We afterwards elixated the remaining Matter with ſeveral Parcels of freſh Water, to get out all the Salt of the Lime; (6.) And now drying the Calx thus deprived of its Salt, we found it would not hold firmly together, but remained quite crumbly or duſty.

Uſes of the Experiment.

25. This Experiment ſhews us the Nature and Compoſition of Lime, which, mixed with Sand, makes the common Mortar uſed in Building. We ſee it is the Alkaline Salt contained in the Lime, and either extricated or produced in calcining the Lime-ſtone, that occaſions the Mortar to concrete and harden, And where the Salt is in its full Proportion, the Lime is ſtrongeſt, and the Mortar hardeſt and moſt durable. This ſaline Principle in Lime is alſo that which gives it the Advantage over Chalk, as a Compoſt for Grounds,

Grounds exhauſted or drained of their natural Salt in Vegetation. For the Alkaline Salt of the Lime, by ſtrongly attracting the Moiſture of the Atmoſphere, and other Particles that float therein, ſwells, dilates, crumbles, and opens the Earth with which it is mixed; whence the Atmoſphere has the freer Action thereon, and in the mean Time the Alkaline Salt of the Lime becomes of a neutral, or nitrous fertilizing Nature.

The Claſs of Saline Earths.

26. Under the general Head of Saline Earths may be reckoned all thoſe that are calcined or burnt in the Fire; as all the Kinds of Lime, Pot-aſh, Salt of Tartar, Soot, &c. theſe being but Mixtures of Salt and Earth: and to ſay the Truth, all Salts appear upon a rigorous Examination to be no other than Earths of different Natures; which, when reduced to a certain Degree of Subtility or Fineneſs of Parts, ſo as permanently to diſſolve in Water, are then emphatically denominated Salts.

Sulphureous Earth.

27. The following Experiment regards the Sulphureous Earths, under which we reckon all thoſe that will flame in the Fire; as Coal, Bitumen, Sulphur, certain crude Ores, Marcaſites, &c.

Marcaſites what.

28. By Marcaſites we underſtand all thoſe Mineral, Earthy and Sulphureous Matters, that are otherwiſe called *Pyrites*, Fire-Stones, Braſs-lumps, Mundicks, or the like. For tho' theſe may be diſtinguiſhed in reſpect of leſſer Differences, yet in general they are all a Compoſition of Sulphur, un-inflammable Earth, and a ſmall Proportion of Metal.

EXPERIMENT V.

The Analyſis of ſulphureous Earths by an Example in Mundick.

Mundick analyſed. 29. We took half a Pound of Mundick reduced to fine Powder, and put it into an earthen Retort, which being placed in a naked Fire, we fitted on a capacious Glaſs-Receiver, and luteing the Juncture well with a Mixture of Loam and Horſe dung, we gave Degrees of Fire up to the ſtrongeſt; then letting all cool and taking off, we found a ſmall Proportion of an acid Liquor, exactly like the Spirit of Sulphur, made by the Bell, at the Bottom of the Receiver, and a conſiderable Quantity of Flowers of Sulphur ſublimed to the Top.

30. The *Caput mortuum* being taken out, and flux'd with half its Weight of clean Iron Filings, afforded a little Lump of a Metallic Subſtance, or *Regulus*.

Uſes of the Experiment. 31. Hence we ſee that Marcaſites chiefly reſolve into Sulphur, and a more fixed earthy Part, which being treated as an Ore yields a Proportion of Metal. And hence perhaps all the Pyrites, Braſs-Lumps, Marcaſites and Mundicks are but cruder Kinds of Ore, and if they could be brought to full Maturity, would prove real Ores.

Marcaſites firing. 32. Theſe Marcaſites, upon long lying in the open Air, attract the Moiſture thereof, thence grow hot, in ſome Meaſure diſſolve, form an Efflореſcence on their Surface, and by Degrees turn into a Vitriol, of the ſame Kind with the Metal they contain Thus if that Metal were Iron, the Vitriol becomes green or martial; if Copper, blue or cupreous. And on this is founded the Artificial Method of making Vitriol, now practiſed in ſeveral Parts of *England*.

Whence Hot Baths, Damps and Fires in Mines, &c.

33. And from the heating, fuming, and firing of theſe Sulphureous Earths, by the Moiſture of the Air, we may perhaps learn the Origin of Hot Baths, Mineral Waters, Damps and Fires in Mines. For it is found, that a Pile of theſe Sulphureous Earths, being barely moiſtened, will at firſt ſmoke, and at length take Fire, and burn like glowing Coals *a*).

How examined for their Metal.

34. Our preſent Experiment likewiſe ſhews us a Way of examining theſe Marcaſites, and of extracting the Metal they may hold, after having firſt ſeparated their Sulphur. Many ſkilful Metalliſts have been impoſed upon by the ſpecious Shew of theſe Marcaſites; for they uſually have a great ſpecific Gravity, and ſome of them a greater than real Ores: whence again they may poſſibly contain the Matter of Metals, tho' in a crude, imperfect, or unfixed State. But to bring this Matter to the Teſt, and to try the Validity thereof, requires more than a common Knowledge in Metallurgy *b*).

Stony Earths.

Our next Species of Earths is the Stony.

EXPERIMENT VI.

That Ignition may deſtroy the Tenacity or Coheſion of Stony Earths, ſhewn in Alabaſter.

Alabaſter calcin'd.

35. (1.) We reduced two Pounds of Alabaſter to fine Powder; then put it into a flat Iron Pan,

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a) See Dr. *Power*'s Experiments, *page* 63.

b) A ſmall Proportion of Silver has been obtained from certain Kinds of Mundick, after the Mundick had been fluxed with Iron Filings, and brought to a Regulus.

and apply'd a ſoft Heat, that the Matter might not glow, yet remain too hot to be touch'd. The Powder was thus brought to flow or run like Quickſilver, and being gently ſtirred, to boil and bubble. We let it continue thus, with a ſoft Heat, till it would run off a Spatula held almoſt horizontal; then removing it from the Fire, it grew cold, and was put into a Glaſs, kept cloſe ſtopped and ſet in a dry Place, under the Name of *Gypſum*, or calcin'd Alabaſter.

(2.) A Parcel of the *Gypſum* thus prepared being brought into a pappy Conſiſtence with Water, the humid Maſs became ſo hard and rigid, in a Quarter of an Hour, as to ring, or afford a clear Sound, when ſtruck with the Finger, or any more ſolid Inſtrument.

(3.) But a Parcel of the ſame Powder being kept in a State of Ignition for ſome time, before it was taken out of the calcining Pan, and then mixed with Water, acquired only a looſe, friable Conſiſtence, or a much leſs Degree of Hardneſs and Tenacity than the other. The un-ignited Sort alſo, by being kept in the open Air, loſes of its coagulating Virtue; and when once conſolidated with Water, becomes unfit for the like Purpoſe again.

Uſes of the Experiment.

36. Thus all the Stony Earths that do not vitrify in the Fire, are by Ignition reduced to fine Powder. So may Flints themſelves, by being often ignited and quenched in Water. And thus white Marble or Cryſtal is reduced to a Powder, fit for the making of pure white Glaſs.

37. This Experiment alſo ſhews us an earthy Matter, apparently fluid over the Fire, that will harden in Water, and ſerves to direct a farther Enquiry after cheap Bodies, that will grow ſtill harder under Water; which might be of

Service in Bridge-works, Water-works, and the like *a*).

38. The preſent Uſe of the Preparation is ſufficiently known, for taking off Faces, Impreſſions and Figures, and the ſtopping of leaky Pipes, or Veſſels that tranſmit or contain Water.

Metallic Earths.

39. The ſixth Claſs is that of *Metallic Earths*: For there are ſome Reaſons to judge, that even Metals themſelves are but a Species of Earths *b*), as they both burn into Aſhes, and melt into Glaſs; whilſt their metallic ductile Form ſeems owing to nothing more than a certain Proportion of Sulphur or Oil contained in them; which being burnt out, leaves them terreſtrial Calces, or certain Metallic Earths, of a nature peculiar to each Metal *c*).

Earths reduced to two general Kinds.

40. And thus we may divide Earths into two general Tribes, *viz.* the *Brittle* or *Friable*, and the *Ductile* or *Malleable*. We have gone thro' the Friable Species; and ſhall proſecute the Ductile hereafter, in our Lectures upon *Mineralogy* and *Metallurgy*.

AXIOMS *and* CANONS.

1. We learn from the foregoing Enquiries, that the Atmoſphere, with its Contents, is a chief Inſtrument in promoting the Fertilization of the Earth, whereby all Vegetables, and thence all Animals are fed, ſupported and maintained *d*); that this Mould may in ſome Meaſure be ſup-

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a) See Mr. *Boyle*'s Philoſophical Works, Abridg. Vol. I. *pag.* 330, 331.

b) See *Becher*'s *Phyſica ſubterranea* paſſim.

c) See *Stahl*'s Comment. *on Becher*'s *Phyſica ſubterranea*; *&* *alibi paſſim.*

d) See *Lect.* III. *paſſim.* See alſo the preſent *Lect. Exp.* I. II.

plied by the Air, at different times *a*), and afterwards by lying immediately under the Turf, receive whatever Richneſs or fine Matter deſcends from above, in the Form of Dews, Rains, Snow, Hail, or other more ſubtile Conveyance; and that this invigorating Subſtance ſoaking thro' the upper Turf, may be thereby defended from the Winds and beating Sun, as by a Skreen, from being exhaled too ſoon again. And thus the Atmoſphere exerciſes a Kind of renovating Power, ſo as to ſupply even exhauſted Earths with freſh Vigour, and fit them for the Production of new Crops *b*). Whence we have a good Rule for renovating and recruiting ſhrunk, withered, and exhauſted Vegetables, by expoſing them to a kindly Atmoſphere, rather than by barely watering them; which might only ſerve to corrupt and ſpoil them the ſooner.

2. That ſome capital Rules may be formed for the Improvement of Agriculture, Horticulture, and the raiſing and improving of Fruit and Foreſt Trees, by finding the Nature, Compoſition, and Ingredients of the Soil wherein each Kind of Grain, Plant and Tree, is moſt delighted *c*.)

3. That it is poſſible, by rational Experiments, to find the beſt Kinds of Steepings for Grain and Seed, and the beſt Kinds of Compoſts and Manure for Land according to the Nature or preſent Exigence of the Soil, or the Fruit intended to be produced; or any one particular Salt, Oil, or Property to be introduced, either into the Ground or Seed *c*).

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a) See *Lect.* III.

b) See *Lect* III. and the preſent, under *Exp.* I. & II.

c) See *Exp.* I & II.

4. That Water, as well as Fire, may be an uſeful Chemical Analyſer in ſome Caſes *a)*.

5. That all vegetable and animal Subſtances, Excrements, *&c.* naturally change and become Compoſt, and at length Mould; whence there is a continual Reciprocation between the animal and vegetable Kingdoms, which thus continually paſs into one another, by the Mediation of the Atmoſphere, Heat, and other natural Agents *b)*.

6. That Compoſts, before they can produce their Effect, muſt in ſome Degree approach the Nature of the Soil they are deſign'd to improve *c)*.

7. That by Earths are underſtood ſuch groſs Subſtances as are of themſelves inſoluble in Water, and indeſtructible in the Fire, yet with fixed Alkaly melt into Glaſs, or with any unctuous Matter aſſume the Form of a Metal, according to their reſpective Natures *d)*; and conſequently, that even Earths, tho' apparently exhauſted ſimple Bodies, have yet their reſpective or peculiar Properties and Effects *e)*.

8. That the moſt fixed Part of Earth has many Inſtrumental Efficacies, not only as floating in the Air, and as forming the Bed or Matrix of Vegetables; but alſo in conſtituting the ſolid Parts or Stamina of all vegetable, animal, and mineral Subſtances *f)*, and affording us all our Veſſels of Glaſs, Stone, Wood, Metal, our Furnaces, Crucibles and Teſts, and being perhaps

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a) See *Exp* I.
b) See *Lect.* III. & *Exp.* I. II. of the preſent.
c) See *Exp.* I & II.
d) See all the *Experiments.*
e) See above, § 5, 26, 38.
f) See *Exp.* I. II. *&c.*

in itſelf the moſt fixed and unchangeable Body in Nature a).

9. That a high Degree of Trituration, or reducing the Particles of certain Bolar Earths, Clays, and ſtony Earths to an extreme Fineneſs, may contribute to the Improvement of the Art of Pottery. For which Purpoſe, Trituration, Sifting, Subſidence in Water, and Decantation, might be uſed to advantage b).

10. That the making of Lime may be improved for the Purpoſes of Building, Manure, and Water-Works, by a due Choice of the Materials, and a ſuitable Calcination c).

11. That ſome conſiderable Uſe and Improvement might, with proper Skill and Application, be made in the Buſineſs of Marcaſites and Mundicks; Bodies uſually eſteemed as Refuſe, and intractable Stuff d).

12. That Marcaſites, by attracting the Moiſture of the Air, may be the efficient Cauſe of ſubterraneous Fires, hot Springs, Damps in Mines, Mineral Waters, *&c.* d).

15. That the Matter of Metals may poſſibly lie looſe, immature, or unconcocted in certain Mineral Matters, ſo as in the Fire to fly away with the Sulphur, or other Parts of the Mineral; unleſs detained, and brought to greater Perfection either by Nature or Art d).

14. That Fire may have the ſame Effect as Air or Time, on certain ſtony Matters, and make them looſe, crumbly, and incoherent e).

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a) See § 15.
b) See *Exp.* III.
c) See *Exp.* IV. § 25. *Exp.* VI. § 36.
d) *Exp.* V.
e) *Exp.* V. & § 35.

LECTURE V.

CONTAINING

A Natural and Chemical Examination of Waters.

1. OUR preſent Buſineſs is the Chemical Examination of Waters; with a view to manifeſt their Natures, their Uſes to the Earth, and all vegetable, animal, and mineral Subſtances; but particularly to Man, ſo far as we can diſcover them. *The Subject.*

2. By the general Name of Water we underſtand an extremely fluid, limpid, inſipid, and inodorous Liquor. This Definition is obvious, and taken from the direct Teſtimony of the Senſes; but by enquiring philoſophically into the Nature of Water, we ſhall find it poſſeſſed of many unexpected Properties. *Water defined.*

EXPERIMENT I.

That Water is contained in many ſolid and, to appearance, dry Bodies.

3. We took a Piece of the hardeſt and dryeſt Bone we could procure, and diſtilling it in an Earthen Retort with Degrees of Fire, obtained a very large Proportion of Water, along with much Oil, and volatile Salt *. *Found in dry Bones.*

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* See this Experiment farther proſecuted in *Lect.* VIII. *Exp.* II.

4. This Experiment holds true even of the oldeſt Hartſhorn, the dryeſt and hardeſt Woods, Earths, and pulverized Stones. Whence it appears, that Water may lie concealed in ſolid Bodies, and make a conſtituent Part thereof; as we formerly ſhew'd of Air *a)*. For we do not here mean that Water inſinuates itſelf into the ſuperficial Pores of Bodies, as Wood, Skins, Leather, Parchment, Strings, *&c.* ſo as to ſwell them in moiſt Weather, and leave them ſhrunk in dry; but that it remains permanently intermixed as an eſſential Ingredient, or Part of ſolid Bodies, as in Stone, or Brick after baking, *&c.* Of this we gave an eminent Inſtance in our laſt Lecture *b)*, where we ſhew'd that *Gypſum*, with Water, preſently concreted to a ſtony Hardneſs.

5. If any doubt ſhould ariſe, whether the Liquor obtained from the Bone in our Experiment be truly aqueous, we might ſhew it to Satisfaction, by ſeparating the Oil, and turning all the volatile Salt contained therein to Sal-Ammoniac, by Means of a ſufficient Quantity of Spirit of Sea-Salt; then rectifying the Liquor by repeated Diſtillation, and bringing it over in Form of a pellucid, inſipid, and inodorous Fluid *c)*.

6. It

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a) Lect. III. *Exp.* X.

b) Exp. VI.

c) To purify this Liquor abſolutely, is a very laborious Taſk; but as ſome of the firſt Drops come over limpid, and almoſt inſipid, before the Oil and Salt begin to riſe, this may afford a ſtrong Suſpicion that the ſucceeding Drops are alſo aqueous, only mix'd with Oil and volatile Salt. For tho' the Bone were ever ſo thoroughly dried by the Fire, and the Veſſels employ'd ever ſo free from Moiſture, a large Proportion of the aqueous Liquor would ſtill be obtained. Beſides, the foul and fetid Liquor has been ſo far cleared from the volatile Salt and Oil, as to appear limpid, and prove inſipid, and

6. It is therefore certain, that all Vegetables, and even the moſt ſolid Parts of Animals, naturally contain a large Proportion of aqueous Fluid, or actual Water, in their Compoſition; and that it remains in them unaltered in its own Nature, ſo as, when ſet free, to reſume the Form of Water, after having been detained, or circulated therein for numbers of Years. Whence it ſhould ſeem, that Water paſſes thro' all Natural Bodies, unchanged either by Accretion, Growth, Appoſition, Fermentation, Putrefaction, Digeſtion, Diſtillation, *&c.* being chemically recoverable again from Vegetables and Animals, Wines, Vinegars, and Spirits.

EXPERIMENT II.

That Water may be collected from the dryeſt Air, or in the hotteſt Climate.

7. (1.) We put half a Pint of common Water into a cylindrical Glaſs, wiped perfectly dry on the Outſide; then added to the Water, two Ounces and three Quarters of pulverized and dry Sal-Ammoniac. We now ſtirr'd them briſkly together; whereupon the Water floating in the external Air was, by the Coldneſs thus produced as the Salt diſſolved within, condenſed on the Outſide of the Glaſs, and trickled down in ſmall Veins into the ſhallow Baſon ſet underneath to receive it. *In the dryeſt Air.*

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and inodorous. And as it approached nearer to common Water, after every Rectification, there is no doubt but, if a ſufficient Quantity were procured, it might by Degrees be brought exactly to reſemble common Water, diſtilled and treated in the ſame Manner. But the eaſieſt Way is to impregnate common Water with the Oil and Salt of the Bone; ſo as to make it reſemble the Mixture that comes from the Bone into the Receiver upon Diſtillation. See more to this Purpoſe in *Lect.* VIII. *Exp.* I. § 14.

The Experiment extended and applied.

1. This Experiment holds in all Climates and Places, of whatever Heights, where it has been tried. Whence, by the Law of Induction, we may make it univerſal, till any contradictory Inſtance appears. Thus therefore it may hold in the moſt parched Countries and hotteſt Seaſons, ſo as to afford an agreeable Method of cooling potable Liquors, and rendering them more refreſhing. For if the Glaſs containing the Salt and Water be ſet in any Liquor, the Liquor will become cooler as the Salt diſſolves. And if any conſiderable Improvement could be made in the Contrivance, it might ſerve in ſome Meaſure to ſupply the thirſty Traveller in parched Deſarts, and Sailors with freſh Water at Sea: nay, it has been a Practice among the latter to hang out Fleeces of Wool on the Sides of the Ship over Night, and to ſqueeze freſh Water out of them in the Morning.

9. The ſame Experiment, being carried higher, affords us a Method of procuring a Degree of freezing Cold, in the hotteſt Countries, at all Seaſons of the Year. For if a Quantity of dry and pulverized Sal Ammoniac be ſeparately included in one well-cloſed Glaſs, and a proper Quantity of common Water in another, and if both theſe Glaſſes be put into the firſt Solution, whilſt the Salt is diſſolving, both the confined Salt and Water will ſoon acquire the ſame Degree of Coldneſs as the firſt Solution; and being then taken out, and mixed together, they will form a ſecond Solution much colder than the firſt. And thus by repeating the Experiment twice or thrice, with freſh Salt and Water, a Degree of freezing Cold may be ſoon obtained in the hotteſt Climate.

EXPERIMENT III.

That an Earthy Subſtance is naturally contained in Water.

Water contains Earth.

10. (1.) We filled three ſeveral Glaſſes with pure Rain Water, Spring-Water, and *Thames*-Water, and let them ſtand cloſe covered for ſome Days before they were exhibited: there was an earthy Sediment then depoſited in all three, but moſt in the *Thames*-Water, the Sediment whereof was not only larger, but alſo more foul and muddy than in the Rain-Water; tho' here alſo it was dirty, perhaps becauſe not carefully collected: whereas in the Pump-Water, it was white, ſcaly, flaky, and ſhining, like fine Spangles of Talc.

11. This Experiment alſo is univerſal, ſo far as it has been tried with Care, and holds true of the Waters of all Species, and all Countries; particularly in thoſe called Mineral Waters, from which an earthy Subſtance may uſually be precipitated by Art, in a conſiderable Proportion: For Example, by the bare Addition of Salt of Tartar.

12. Certain Experiments carefully made, and repeated, ſhew that the terreſtrial Matter naturally contained in Water, has a principal Share in the Growth and Increaſe of Vegetables; all the Plants that thrive in Water, appearing to enlarge their Bulk in Proportion to the earthy Matter furniſhed by the Water. Whence pure Elementary Water ſeems but a Kind of Vehicle to convey this nutrimental or ſubſtantial Part, and depoſite it in the Veſſels through which the Water moves, in order to its general Exit at the Surface of Vegetables *. Yet we are not here

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* See Dr. *Woodward*'s Experiments to this Purpoſe, in the *Philoſophical Tranſactions.*

to exclude the Inſtrumental Efficacy of the two other Elements, Fire and Air. Now this appearing to be the general Office of Water, in the whole Vegetable and Animal Kingdoms, *viz.* the Conveyance or Diſtribution of the alimentary Matter to all their Parts, it may be proper to conſider its Phyſical Properties, which wonderfully fit it for this Office.

Office and Uſe of Water.

Its Properties.

13. The Figure of its component Parts appears to be ſmooth and ſpherical, like thoſe of Quickſilver, whence it becomes extremely moveable and penetrating. Thus it readily enters the Pores of Wood, Leather, Skins, Chords, Muſical Strings, *&c.* and thus it likewiſe becomes capable of moving and agitating Particles of Matter leſs active than itſelf, and ſo proves the more immediate Phyſical Agent of Fermentation, Putrefaction, Solution, *&c.* And thus it alſo conveys earthy and ſaline Matters thro' our Filtres of Paper, Stone, *&c.* and even raiſes ſome Proportion of them in Diſtillations.

14. Its Particles likewiſe appear to be extremely minute, and ſo to have a large Share of Surface. Hence Water is admirably fitted for a Solvent, or for readily entring the Pores of Salts, and coming into full Contact with all their Particles. And thus it will paſs, where Air cannot, on Account of its Moiſture, or lubricating Power, whereby it ſoftens mucilaginous Matters, and will therefore ſoak thro' the cloſe Pores of a Bladder. And being thus qualified, it ſeems extremely well fitted to enter or ſlide thro' the fine Canals and Veſſels of Plants; ſo as to convey nutritious, ſaline, or earthy Particles along with itſelf; and having depoſited them by the Way, and being now robbed of all that is uſeful to the Individuals, it at length perſpires into the open Atmoſphere, in order to be there recruited and

fitted for freſh Service. And the ſame kind of Office it performs in Animal Bodies.

15. Hence we may learn the phyſical Reaſon why River-water is more fertilizing than Rain, *viz.* becauſe it contains more earthy Matter; and why ſuch Meadow and Paſture Lands, as lie commodious to be overflowed by muddy Rivers, yield greater Crops than ſuch as are watered by other Means. Hence the incredible Fertility of *Egypt* appears to proceed from the turbid Overflowing of the *Nile*, and the ſame is to be underſtood, in ſome Degree, of other Rivers, as the *Ganges*, the *Thames*, &c *a)*.

That of Rivers why moſt fertilizing.

EXPERIMENT IV.

That Water ſaturated with one Body will ſtill diſſolve another.

16. (1.) We took four Ounces of pure cold Rain-water, and diſſolved therein as much dry common Salt, reduced to Powder, as it would take up. The Salt uſed being Part of a known Quantity, we weighed the Remainder, to find preciſely how much had been employ'd, and found it about an Ounce; which therefore gave the Meaſure of the Power that the Water had to diſſolve common Salt, with the Degree of Heat then preſent in the Atmoſphere. To this ſaturated Solution of Sea-Salt we added about two Scruples of dry pulverized Nitre, and found that it diſſolved therein, tho' no more common Salt could be taken up by the Water.

The diſſolving Power of Water.

17. This Experiment is only particular; for the diſſolving Power of Water is different on

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a) See *Boyle*'s Abridgment. Vol. I. *pag.* 248. *&c.* and *Lowthorp*'s Abridgment of the Philoſophical Tranſactions, Vol. II. *pag.* 725. *&c.*

different Subjects a). Whence a Set of Experiments ſhould be made, to ſhew this Power on all the Salts, and other Subjects, whether mucilaginous, gummy, earthy or others, that are capable of diſſolving in Water. Such a Set of Experiments might prove of conſiderable Uſe in phyſical and chemical Enquiries, and help to rectify the Mind, which is extremely apt to form general Rules from a few particular Inſtances. Whence Water has often paſſed for a Kind of univerſal Solvent; tho' there are numerous Bodies which it will not diſſolve b). And from this erroneous Notion of a general diſſolving Power in Water, the Enquiry into Mineral Waters has been in great Meaſure either ſtopped, or perverted c).

18. The limited Power which Water has, of diſſolving common Salt, appears remarkably in the Ocean; which we ſee, by our Experiment, may naturally contain about one fourth Part of ſuch Salt; or, with an additional Heat, conſiderably more; tho' its Charge is always limited by the Nature of the Thing, and cannot be above one certain Proportion. This, however, is found to differ in different Seas, or Bays; the Water of ſome being found to yield more Salt than others, according to the greater Heat or Exhalation of Vapor in thoſe Seas or Bays; or again, perhaps, according to the Opportunity which the Water has had of running upon a more ſaline Bottom &c.

19. But when Water has diſſolved its full Proportion of common Salt, we ſee, by the

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a) As will appear hereafter. *Lect.* VI. *Exp.* I.

b) As Stones, Metals, Glaſs, Gems, Amber, Shells, Coral, Sponge, Cloth, &c. See hereafter *Lect.* VI. §. 15.

c) See the *Appendix* to *New Experiments and Obſervations* upon *Mineral Waters*, lately publiſhed.

Experiment, that it may ſtill diſſolve ſome Quantity of another Salt. And how far this Power may extend, as to the Matters at the ſame time diſſolvable in Water, has not been hitherto ſufficiently aſcertained *a)*.

20. Nor is the Method, wherein different Salts range themſelves in the ſame Water, preciſely determined. That they do not intermix, ſo as inextricably to entangle and confound their Particles among one another, appears from Cryſtallization. For if ſeveral different Salts be diſſolved together in the ſame Parcel of Water, they may be made to ſhoot ſeparately out of it again, by repeated Evaporation and Cryſtallization, each in its own natural Form and Figure, or pure and unmixed with the reſt. But the Power of Water as a Solvent will again come to be conſidered in our next *Lecture upon Menſtruums b)*.

EXPERIMENT V.

The natural Ingredients or different component Parts of Water.

The Contents of Water.

21. (1.) We took a Pint of the pureſt Rain Water, decanted from its natural Sediment, and put it into a bellied Glaſs, with a long ſlender Stem; then marked the Part of the Stem to which the Water roſe, and ſet it in the exhauſted Receiver, where we found it manifeſtly expanded, and diſcharged many Bubbles of Air. (2.) We put the ſame Water into a clean Glaſs Retort, and diſtilling with a gentle Heat into a Glaſs-Receiver, there came over a pure light Water, or merely aqueous Liquor; leaving a

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a) See Dr. *Grew* and Mr. *Boyle paſſim.*
b) See *Lect.* VI. *Exp.* 1.

ſmall Quantity of dry and whitiſh terreſtrial Matter behind.

22. This Experiment requires a farther, and much more exact Proſecution. We ſee it reſolves Water into three diſtinct, and, to appearance, different Parts; *viz.* (1.) Air, (2.) elementary Water, and (3.) Earth. The Truth of this Analyſis ſeems confirmed by other Experiments. For Water, by boiling, is alſo deprived of the Air it naturally contains. And ſo it likewiſe is by ſtrong Freezing, the Ice becoming gradually leſs porous, and more purged of its Air-Bubbles; alſo Water upon thawing always leaves a Quantity of earthy Sediment behind. But neither this Experiment of Freezing and Thawing, nor the Re-diſtillation of Water, has been carried ſo far as to ſhew, with Certainty, whether any, and what Proportion of the Water is thus actually convertible into Earth; or whether a Quantity of earthy Matter, before diſſolved or finely diſperſed in the Water, is thus only aggregated, or collected together and left behind, in a dry, ſolid, or earthy Form, upon Evaporation.

23. The Determination of this Point is of Conſequence to Phyſicks. The Circumſtances that tend to invalidate the Experiment by Diſtillation are, (1.) That the Water ſuffers a great Diminution of its Quantity in the Operation; ſome Part ſticking to the Sides of the Veſſels employed every Time, and ſome tranſuding thro' the Luting: whence the Account is defrauded. And (2.) that in tranſvaſing the Liquor, it every Time licks up the Duſt naturally contained in the Atmoſphere, and at the ſame Time loſes Particles of Water, which are thus carried off by the Air; whence, upon numerous Repetitions of the Experiment, a large Proportion of the Earth ob-

tained may proceed from the Duſt of the Atmoſphere *a)*.

24. The Experiment by Congelation ſeems attended with fewer Difficulties, and might perhaps be brought to determine the Point with leſs Exception, by uſing a Circle of Freezings and Thawings, alternately repeated, with Care to ſeparate the Earth each Time.

25. What we here term Elementary Water, is the pure aqueous Part which comes over in Diſtillation, commonly called by the Name of diſtilled Water. This diſtilled Water is found to be lighter and purer than the natural; provided it acquire no Foulneſs, or heterogenous Parts in the Operation. And it is obſervable that, if the Operation be ſtopped in the Middle, a groſſer Water remains behind than what came over. Whence, for all curious chemical and œconomical Uſes, the Water employed ſhould not boil too long; as particularly in the making of Tinctures, Tea, Coffee, *&c.*

EXPERIMENT VI.

The more commodious Methods of examining Water.

26. By Means of the Inſtrument called the Hydroſtatical Balance, we took the ſpecific Gravity of the Water propoſed, and directly judged of its Goodneſs by its Lightneſs. *Common Water examined.*

27. This Experiment is a good Subſtitute for ſeveral other Ways of examining the Purity and Goodneſs of Waters, both common and mineral. For it appears by numerous Inſtances, that light Waters are, *cæteris paribus*, the beſt, pureſt and wholeſomeſt.

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a) See Mr. *Boyle*'s Philoſophical Works, and *Boerhaave*'s Chemiſtry.

28. But as the preſent Method requires the Uſe of a curious Inſtrument, and a conſiderable Degree of Accuracy and Attention, other more expeditious, tho' not more exact, Trials have been invented; particularly by the Uſe of *Water-Poiſes*; which are Inſtruments of Ivory, Glaſs, *&c.* made hollow-bellied, ſo as to float in Water, higher or lower, according as the ſpecific Gravity thereof is more or leſs: And the Inſtruments being graduated or divided by Lines on the Stem, readily ſhew to the Eye the Difference betwixt the ſpecific Gravities of any two Waters propoſed; tho' not with the utmoſt Exactneſs.

29. The Foundation of both Experiments is this, that the Bodies diſſolved or licked up by Water, in its paſſing thro' the Caverns, or ſuperficial Parts of the Earth, are generally either ſaline or earthy; which being both more ponderous than pure Water, it follows, that the ligheſt Waters are leaſt impregnated with them, and therefore fitteſt for the finer Uſes, where no ſuch groſs, ſaline, or earthy Matters are required; as they are not particularly in the healthy human Body, where the ordinary Office of common Water is to convey and diſtribute Nutriment to all the Parts, to dilute and waſh off the Overproportion of animal Salts, as it evidently does in Sweat and Urine.

30. By Means of the preſent Experiment we find, that the pureſt Rain-Water is of nearly the ſame ſpecific Gravity with diſtilled Water; neither of them, when obtained pure, precipitating any groſs earthy Matter upon the Addition of Oil of Tartar *per deliquium*, as many Spring-Waters do.

31. Common-Waters are diſtinguiſhed into *Hard* and *Soft*, and accordingly are uſed for different Operations. Thus ſoft Water is found beſt

for extracting certain Tinctures, freeing Metallic *Calces* from their Salts, &c. And hard Water is beſt for the tempering of Steel, the making of artificial Wines, and Malt-Liquors intended for long keeping.

32. Hard Waters are ſuch as contain a foreign, ſaline or terreſtrial Matter; and accordingly become ſofter by long ſtanding, or by a ſmall Addition of Salt of Tartar; both which tend to precipitate the terreſtrial Subſtance out of them.

EXPERIMENT VII.

The more commodious Methods of examining Mineral Waters.

33. (1.) To half a common Wine-Glaſs of *Pyrmont* Water we added a Dram of the Syrup of Violets, whereby a greeniſh Colour was produced. (2.) To a like Quantity of the ſame Water we added a few Grains of ſcraped Galls; and firſt, a purple, then a blackiſh Colour preſently enſued. (3.) We evaporated a Quantity of the ſame Water, and a ſmall Proportion of an ochry Subſtance was left behind. (4.) We ſet a Glaſs of the ſame Water, cold, in the Receiver of the Air-Pump, and found, upon with-drawing the Air, that the Water ſparkled violently, and diſcharged a numerous Quantity of ſmall Bubbles at its Surface; like what happens in the Conflict of an acid and alkaline Liquor. *Mineral Waters examined.*

34. This Experiment holds in all the Caſes of Chalybeate Waters only, and not of *Mineral Waters* in general. By Mineral Waters, in general, are meant all thoſe wherein any Medicinal Virtues, beſides thoſe of common Water, are found. Theſe Mineral Waters are of various Kinds: we may conſider them under the general Titles of *Chalybeate*, *Purgative*, and *Alterative*.

35. The more uſeful and commodious Additions for examining theſe three Kinds of Mineral Waters, are, *Galls*, *Syrup of Violets*, and *Oil of Tartar per deliquium.*

36. *Galls* diſcover in them any ſmall Proportion of Vitriol or diſſolved Iron; as having the Property of immediately ſtriking a purple, or black Colour, in all Waters, where any ſuch Subſtance is lodged.

37. *Syrup of Violets* in the ſame Manner diſcovers any ſmall Predominancy of an Acid or Alkali therein; by changing the Water red, if an Acid, and green, if an Alkali preſides.

38. *Oil of Tartar* diſcovers any ſmall Proportion of earthy Matter, leſs capable of diſſolving in Water than that Salt; by precipitating ſuch earthy Matter, in Form of a white Cloud, to the Bottom of the containing Glaſs, where it collects, and appears like a ſubtile white Powder.

39. Theſe Particulars may be ſhewn, and proved ſatisfactorily, by adding to pure Water a little of a known Acid, Alkali, diſſolved Iron, and ſubtile Earth, or fine light Sediment of an earthy Water, and then applying the Syrup of Violets, Galls, and Oil of Tartar reſpectively.

40. Suppoſe, therefore, any unexperienced Water to be examined; firſt, drop into it a little Syrup of Violets, and if this does not alter its Colour, but keeps its full natural Blueneſs, the Water is neither Acid nor Alkaline. If Galls do not turn the Water black, it is not Irony, nor Vitriolic; and if Oil of Tartar does not precipitate a white Powder, the Water holds no conſiſiderable Proportion of earthy Matter.

41. The preſent Set of Experiments is capable of great Enlargement, by Means of many other Additions, fitted to produce a Change of Colour, or a Precipitation in Waters, according

they are impregnated with Matters of certain Kinds. Thus a Solution of Silver, by cauſing a Thickneſs or light Precipitation, diſcovers a minute Proportion of Sea-Salt contain'd in Waters. And there is ſcarce a Salt, an Earth, or a Mineral, hitherto known, but the Induſtry of the Chemiſt has found Means of diſcovering, if it be contained in any common or Mineral Water; eſpecially, if to this we add the Uſe of Evaporation, or the Way of bringing the ſolid Contents of ſuch Waters to a dry Form. So that if this whole Affair were to be properly conducted, we apprehend it might in a ſhort Time terminate in a certain Diſcovery of the Contents of all the Mineral Waters of the Kingdom; to the great Advantage of ordinary Life, and a conſiderable Improvement in the Art of Medicine, and many other mechanical Arts and Trades, depending upon the proper Choice and Uſe of Waters.

EXPERIMENT VIII.

That Mineral Waters are imitable by Art.

Pyrmont *Water imitated.*

42. We took a Quart of the lighteſt and pureſt Water we could procure, and added to it about thirty Drops of a ſtrong Solution of Iron made with Spirit of Salt, a Dram or more of *Oleum Tartari per deliquium*, and twenty, thirty, or forty Drops of Spirit of Vitriol; but ſo as that the Alkali of the Oil of Tartar might prevail: we now ſhook all briſkly together, and poured out a Glaſs for taſting; upon which, it was found very remarkably to reſemble *Pyrmont-Water*.

43. This Experiment, tho' but particular, may afford us a general Rule for imitating any Mineral Water propoſed. The Rule is, by a proper Analyſis to find the Contents of ſuch a

Water, and their Proportions, by Evaporation, the Addition of tinging Ingredients, *&c.* as above mentioned *a)*; then, by Means of ſynthetical Chemiſtry *b)*, to compoſe a ſimilar Mixture. Thus, for Example, we learn, by a proper Analyſis, that the Ingredients or different conſtituent Parts of *Pyrmont*-Water *c)*, are a ſubtile aqueous Fluid, a volatile Iron, and a predominating Alkali; all joined together into one briſk, pungent, ſpirituous Water: And upon this Analyſis our preceding Imitation was founded, by means whereof, if the Proportions be juſtly hit, the artificial *Pyrmont* Water will greatly reſemble the natural, and produce ſimilar Effects in the Body; as has been found upon Experience *d)*.

44. The Imitation of this ſpirituous Kind of chalybeate Water is by much the moſt difficult; and may perhaps be rendered more perfect, if, inſtead of uſing the Solution of Iron in Spirit of Salt, the pureſt common Water be boiled in a cloſe Veſſel, with a ſmall Proportion of Okre, ſoft Iron Ore, or Pyrites; the reſt of the Proceſs being conducted as above ſet down.

Purging Waters imitated.

45. The Imitation of the common purgative Mineral Waters is facile: Thus *Epſom*-Water is imitated by barely diſſolving three or four Drams of *Epſom* Salt in a Quart of pure Water, made ſomewhat briſk or quick with a few Drops of Spirit of Vitriol and Oil of Tartar *per deliquium*, ſo as to let the Alkali prevail. And the ſame is to be underſtood of any other Water, the Contents of which are exactly known.

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a) See *Exp.* VII. §. 35, 36, 37, *&c.*

b) See hereafter the *Lecture* on Synthetical Chemiſtry.

c) See above *Exp.* VII.

d) See New Experiments and Obſervations upon Mineral Waters.

46. And by a little farther Experience and Application, we apprehend that theſe Imitations might be brought to a great Degree of Perfection; ſo as to render the Trouble and Charge of importing foreign Waters, or going to drink them abroad, in a Manner unneceſſary.

The Experiment extended.

But the Imitation of the alterative Waters, ſuch as thoſe of *Bath*, *Buckſton*, *Holt*, *&c.* has hitherto ſcarce been attempted; nor can be rationally, for Want of their reſpective juſt Analyſes, upon which ſuch Imitations ſhould always be grounded.

AXIOMS *and* CANONS.

1. We have ſeen, (1.) that Water is naturally contained in ſome of the dryeſt and hardeſt Bodies, and in the dryeſt Air; (2.) that itſelf naturally contains Air, and an earthy Subſtance; (3.) that it is the proper Menſtruum of Salts, diſſolving more of one and leſs of another; (4.) that one good Sign of its Purity and Wholeſomeneſs is its Levity; (5.) that the Ingredients of a mineral Water may be diſcovered by chemical Experiments; and (6.) that mineral Waters are imitable by Art, guided by ſuch Diſcovery *a)*.

2. That Water is of infinite Uſe in all the Works both of Nature and Art, as without it there could be no Generation, Nutrition, or Accretion performed in all the animal, vegetable, mineral, marine and atmoſpherical Regions. The Blood could not flow in the Veins, nor the Sap in the Veſſels of Vegetables, nor the Particles of Minerals concrete and grow together, without Water. It is this that makes the largeſt Part of

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a) See the *Lecture paſſim.*

our Blood, our Drink, and our Aliment. Without it there could be no Corruption, Fermentation, or Diſſolution carried on *a)*; no Brewing, no Diſtilling, no Wines, no Vinegars, no Spirits *b)*.

3. That we meet with Water under an infinite Variety of Forms, and in an infinite Variety of Bodies; as of Air, Vapour, Clouds, Snow, Hail, Ice, Sap, Wines, Blood, Fleſh, Bone, Horn, Stones *&c.* through all which it ſeems to paſs unaltered, as an Agent or Inſtrument that ſuffers no Alteration by Re-action, but remains capable of reſuming the Form of Water again upon Occaſion *c)*. In which reſpect it greatly reſembles that other *Proteus* Quickſilver, which we meet with in the Form of Fumes, Clouds, Sublimate, Precipitate, *&c.* from which it may be reduced to running Mercury again *d)*.

4. That Water, in its common State, appears to be a Combination of all the Elements together, as containing a Quantity of Fire, which keeps it fluid, a Quantity of Air, and a Quantity of Earth *e)*. Whence it can be no Wonder that Water alone, as it appears to the Senſes, ſhould ſuffice for Vegetation, in ſome Caſes where little Earth is wanted; or for ſupporting animal and mineral Life, where no great Degree of Nutriment is required. And hence it proves a *Gluten* or Cement to ſome Bodies, and a Solvent to others. Thus it conſolidates Brick, Plaiſter of *Paris*, Stone, Bone, *&c.* but diſſolves Salts, and ſubtile Earths approaching to Salts, and becomes the inſtrumental Cauſe of their Action *f)*.

a) See *Lect.* I. *b)* See the whole Work *paſſim.*
c) See *Exp.* I. *&c.* See alſo *Lect.* III.
d) See Mr. *Boyle* paſſim. *e)* See *Lect.* I. II. III. IV.
f) See *Lect.* I. the preceding *Lecture* paſſim; and again, the *Lecture* upon Fermentation, *&c.*

5. That Water conveys Nouriſhment, or a more fixed and ſolid Matter, to the Parts of Vegetables, where that being depoſited the finer Fluid perſpires into the Atmoſphere *a)*; which gives us the phyſical Cauſe of the Dampneſs and Unwholeſomeneſs of woody Countries, which they remarkably find in *America*. For all large Vegetables act after the Manner of Pumps, continually drawing in large Quantities of Water at their Roots, and diſcharging it at their Leaves; which intimates a Method of collecting Water in dry Countries, and alſo of making Salt-Water freſh.

6. That the Water in paſſing thro' Plants, after having depoſited its more terreſtrial Part, does not always go off pure, but impregnated with the finer Effluvia, or more ſubtile Particles of the Vegetable; thus making an Atmoſphere round every Plant, odoriferous or otherwiſe according to its Nature: which ſupplies us with a Rule for procuring the odoriferous Waters of Vegetables by Diſtillation *b)*.

7. That the Particles, which are not fine enough to go off thus along with the Water, are left behind upon the Surface of the Leaves and Flowers of Plants; being now thickened or ſtrained from their moiſter Parts, and remaining in the Form of Honey, Manna, Gums, Balſams, *&c.* according to the Nature of the Vegetable *c)*. And hence appears the phyſical Cauſe of Plants proving more odoriferous and ſweet, when the Weather is both warm and moiſt; as immediately after a Summer's Shower.

8. That the chemical Operator ſhould form to himſelf an *Hygrometer d)*, for the Service of his

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a) See *Exp.* III. *&c.* *b)* See *Exp.* III. §. 12. *&c.*

c) See *Exp.* III.

d) As of Sponge, Salt of Tartar, Oil of Vitriol, Oat-beards, *&c.* which attract the Moiſture of the Air.

Laboratory, to determine the Proportion of Water at all Times contained in the Air; which continually mixes with his Preparations, differently augments their Weight, and promotes or hinders many of his Operations *a)*, as we find particularly in making the *Oleum Sulphuris per Campanam* and *Oleum Tartari per deliquium*, both of which ſucceed beſt in a moiſt Air.

9. That pure Water makes the largeſt Part of mineral Waters, where it is impregnated as a Menſtruum with ſeveral Ingredients, which it diſſolves or takes up in its Paſſage thro' the Earth *c*).

10. *Laſtly*, The preceding Enquiry affords conſiderable Light for diſcovering practicable Ways of making Sea-Water freſh and potable *c)*; and of preparing Waters by Art, ſo as to render them fitter for the common œconomical Uſes, and the Service of many particular Arts; as Medicine, Pharmacy, Chemiſtry, Brewing, Diſtilling, *&c. d)*

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a) See *Exp.* II. See alſo *Lect.* III. *paſſim.*
b) See *Exp.* VII. VIII.
c) See §. 7, 12, 14, & *Ax.* 5, *&c.*
d) See §. 40. *&c.*

LECTURE VI.

CONTAINING

An Enquiry into the Nature and Uſe of Menſtruums, or Solvents.

1. WE have now gone thro' the common Elements, Fire, Air, Earth, and Water: we next proceed to *Menſtruums*, which make a large Branch of Natural Philoſophy, and a more peculiar and immediate Part of Chemiſtry. *Introduction.*

2. By *Menſtruums* we underſtand all thoſe Bodies, which, in a fluid, or ſubtilized State, are capable of interpoſing their ſmall Parts betwixt the ſmall Parts of other Bodies, ſo as to divide them ſubtilely, and form a new uniform Compound of the two. *Menſtruums what.*

3. Hence ſolid Bodies, as well as Fluids, are capable of becoming Menſtruums, when their Parts are ſubtilely divided, ſo as to receive others uniformly between them; whether this ſubtile Diviſion and joint Interpoſition of Parts be effected by Fuſion, Triture, or the like. *Solid and Fluid.*

4. Thus when two Metals, being fuſed together, mutually interpoſe their ſubtile Parts between each other, and unite into one uniform Maſs, they become Menſtruums to each other. And ſo when common Sulphur and common Mercury are barely rubbed together, till the Maſs becomes every Way uniform and ſimilar, the Sulphur proves a Menſtruum to the Mercury, and the Mercury a Menſtruum to the Sulphur; and *The Definition illuſtrated.*

and both uniting form that black uniform Powder called *Æthiops Mineralis.*

5. Whence it appears, that the Term *Menſtruum* is equally applicable to both the Bodies concerned; the one being as much a Menſtruum as the other. So when Water diſſolves Sugar, it may as juſtly be ſaid that the Sugar diſſolves the Water; tho' Cuſtom, and the common Forms of Speech, which have little Regard to juſt and philoſophical Notions, do not authorize the Expreſſion.

The Menſtruums of Nature.

6. And hence it may appear that the common Elements, which we have conſidered in the foregoing Lectures, are in a proper Senſe the *Menſtruums of Nature*, which ſhe employs for producing her ordinary Effects. For Fire mixes uniformly among Bodies, and divides their Parts; ſo does Air, Water, and elementary Earth, as we have all along ſhewn. We ſuppoſe it will not therefore appear foreign, but directly conducive to our Purpoſe, to have beſtowed a Lecture upon each of theſe Elements, by way of Foundation for our Courſe; as theſe are not only the principal Agents of Nature, but are alſo concerned in every chemical Operation.

The Purport of the Experiments.

7. The preſent Buſineſs will be to ſhew, (1.) the different diſſolving Powers of Water, on different Bodies. (2.) The ſame of Alcohol. (3.) The ſame of Oil. (4.) The ſame of unlikely Subſtances. (5.) The ſame of Quickſilver. (6.) The ſame of the common Menſtruums, *Aqua Fortis* and *Aqua Regia*. And (7.) the ſame of the Digeſtor: thus proceeding gradually from the weakeſt up to the ſtrongeſt diſſolving Powers hitherto known in Chemiſtry.

EXPERI-

EXPERIMENT I.

That Water, as a Menſtruum, *diſſolves more of one Body, and leſs of another.*

The different Powers of Water, as a Menſtruum.

8. We took three ſimilar and equal Glaſſes each containing two Ounces of the ſame Kind of Water, cold; into the firſt we put a certain weighed Quantity of *Epſom* Salt, *viz* two Ounces, the greateſt Part whereof was ſoon diſſolved; into the ſecond we put a certain weighed Quantity of dry and pulverized common Salt, *viz.* five Drachms, which likewiſe ſoon diſſolved almoſt entirely; into the third we put a certain weighed Quantity, *viz.* eight Grains, of finely pulverized *Cream of Tartar*, whereof ſcarce any Part appeared to diſſolve in the cold. We ſet all the Glaſſes in *Balneo Mariæ*, till the Water of the *Balneum* boiled, and then obſerved that more of each Salt was taken up reſpectively.

The Experiment extended.

9. It might be proper, for the further Improvement of Chemiſtry and Natural Philoſophy, to form a Table of the Time and Quantity wherein all the known Salts are diſſolvable in Water. *Epſom* Salt, we ſee, preſently diſſolves in about an equal Quantity of Water; common Salt diſſolves in about four times; Nitre in about five or ſix times; and Salt of Tartar in about twice its own Quantity of Water: but *Cream of Tartar* requires twenty times its own Quantity of boiling Water to diſſolve it.

10. Such a Table, regularly formed, might eaſe the Trouble of refining Salts, by ſhewing at once, without future Trial or Loſs of Time, how much Water each Salt required to diſſolve it; for Clarification, Filtration, or Cryſtallization.

11. It would likewiſe ſupply us with a ready and commodious Way of ſeparating any Mixture

of Salts, by ſhewing which would firſt ſhoot out of the Mixture upon Cryſtallization. For the Rule is, that *the Salt which requires the largeſt Proportion of Water to diſſolve it will ſhoot the firſt.* And thus Nitre, requiring a larger Proportion of Water to diſſolve it than common Salt does, the former is, in the ordinary way of refining, totally ſeparated from the latter by Cryſtallization. And unleſs this were to happen, the *Aqua-Fortis* prepared from Nitre would prove a kind of *Aqua-Regia*, and, inſtead of diſſolving Silver, would diſſolve Gold; For *Aqua-Regia* is made from a Mixture of Nitre and Sea-Salt, or Sal-Ammoniac, which contains the Spirit of Sea-Salt *.

12. The ſame Table might alſo direct us to a ready and commodious Method of ſeparating two Salts, without waiting for Cryſtallization. Thus ſuppoſe *Tartar of Vitriol* mixed with *Epſom* Salt, if Water be poured upon the Mixture, it will preſently diſſolve the *Epſom* Salt, leaving the *Tartar of Vitriol* untouched, ſo that it may be decanted clear from it; becauſe *Epſom* Salt eaſily and plentifully diſſolves in cold Water, whereas *Tartar of Vitriol* diſſolves ſlowly and ſparingly in it. And the ſame is to be underſtood of other Mixtures of Salts.

Accounted for.

13. If the phyſical Reaſon be demanded, why one Salt diſſolves more readily in Water than another, we recommend it to farther Examination whether all Salts do not diſſolve in Water with greater or leſs Facility, and in greater or leſs Proportion, according as they contain more or leſs of a groſs, unctuous Subſtance, unſuitable to the Nature, or to the Fineneſs and Lubricity of Parts required in Water. The comparing of

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* See hereafter *Exp.* VI.

Epſom Salt, Salt of Tartar, common Salt, *&c.* with Nitre, Alum, crude Tartar, *&c.* ſeem to make this more than a Conjecture.

14. Vitriols alſo, being a Species of Salts, thence become ſoluble in Water. But pure Water has not the Power of diſſolving Metals, unleſs they are firſt reduced to a Saline or Vitriolic Form: Nor does Water act as a *Menſtruum* upon Oils, Roſins, Amber, Sulphur, *&c.* Whence its Power, as a direct Solvent, is limited *. For Salts it ſeems the appropriated *Menſtruum*; but, with the Aſſiſtance of other things, it may diſſolve a great Number of other Bodies: Thus, by the Interpoſition of Wax, it will diſſolve Oil by ſimple Triture; by means of the Yolk of an Egg it will diſſolve Turpentine; and by means of acid Spirits it will diſſolve Chalk, Earths, and Metals.

15. In our preſent Experiment we find the diſſolving Power of Water increaſe with Heat; and this holds till the Water boils: after which, as the Heat remains the ſame, ſo does the diſſolving Power, and as this Heat decreaſes, ſo does that Power, letting Part of the Salt fall down again. Whence it ſhould ſeem as if Heat was the original Cauſe of the diſſolving Power.

16. But on the other Hand, there are Experiments wherein the Power of Water, as a *Menſtruum*, decreaſes, as the Degree of Heat increaſes; as in boiling the White of an Egg; where the Water, as it grows hot, coagulates the Subject which it would diſſolve when cold. We alſo obſerve the ſame of Blood, a firm Mixture of Flower and Water, *&c.* The Inſtances of this Kind ſhould therefore be collected, and go along with the former, to prevent the Mind from running

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* See *Lect.* V. §. 17, 18, &c.

ing into Error, by concluding haſtily from too few Experiments, which has greatly prejudiced Chemiſtry and Natural Philoſophy.

EXPERIMENT II.

The diſſolving Power of Alcohol.

Camphire diſſolved in Spirit of Wine.

17. We took an Ounce of *Alcohol*, and by degrees added to it an Ounce of ſolid Camphire; all which it nearly diſſolved, in a very ſhort Time, without any Ebullition, or apparent Alteration of Fluidity or Tranſparency. We afterwards poured in a large Proportion of fair Water, which weakening the Solution, and uniting with the *Alcohol*, cauſed it to let go the Camphire; ſo that now it all roſe, white, ſolid, and perfect, to the Top of the Mixture.

Alcohol *what.*

18. *Alcohol*, or highly rectified Spirit of Wine, is a Liquor obtained from vegetable Subjects, by Fermentation, Diſtillation, and Rectification *a*). It appears related to Oil, becauſe totally inflammable; and when carefully examined, to be the eſſential Oil of the Vegetable, intimately broke, and ground in among the Particles of Water; ſo as to form one uniform Liquor, not eaſily ſeparable again into different Parts *b*).

19. We learn, by the preſent Experiment, that it has the Power of diſſolving about its own Weight of Camphire; which when duly examined, appears to be a particular Kind of volatile, or eſſential Oil, coagulated into a white and ſolid Subſtance *b*): And, as ſuch an Oil, it is here plentifully diſſolved in *Alcohol*.

Its Uſes.

20. This *Alcohol* is a capital *Menſtruum* in Chemiſtry, and fitted to diſſolve Roſins, as well

a) See the *Lecture* upon *Diſtillation* hereafter.

b) See hereafter *Lect.* XVI. *Exp.* III.

as Oils; tho' it does not thus mix inextricably with either, but leaves them ſeparable again by the bare Addition of Water, which it diſſolves more readily than either Oil or Roſin, and therefore lets them go to join with this, according to the Law of Precipitation. For *whenever one Body has diſſolved another, if a third be added to the Solution, which third has a greater Relation to either of the former, than they have to each other, their Union is ſeparated, and the third Body diſſolved inſtead of the firſt or ſecond; one of which is now at Liberty to riſe, or fall to the Bottom, according to its ſpecific Gravity:* as we ſaw remarkably in the preſent Experiment, where the Camphire, diſſolved in the Spirit of Wine, was ſoon made to float upon the Surface, by the Addition of Water, which has a greater Appetite of Union, or Relation, to Spirit of Wine, than that Spirit has to Camphire. And the phyſical Reaſon hereof may appear from what was juſt now ſaid of the Compoſition of this Spirit, or its being an intimate Mixture of Water and volatile Oil *.

21. Hence *Alcohol* is an intermediate Subſtance betwixt Oil and Water, and related to both, tho' participating more of Water than of Oil: And according to theſe Relations, its Action as a *Menſtruum* may, we conceive, be properly explained.

22. By means of this *Menſtruum* the Tinctures of *Myrrh*, *Gum Lac*, *Guaiacum*, moſt of the Varniſhes, and many medicinal Tinctures, Elixirs, and Solutions are prepared; tho' for theſe Purpoſes it uſually requires to be acuated with Salt of Tartar. But our preſent Buſineſs is to conſider the Power of ſimple *Menſtruums*, rather than of ſuch as are mixed; for that were an infinite Field, and would lead us too far for the preſent.

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* See §. 18.

Tho' the Diſcovery of powerful, yet innocent *Menſtruums*, by means of Compoſition, ſhould be earneſtly recommended to the Diligence of every Chemiſt, as that on which the Improvement of numerous Arts depends.

EXPERIMENT III.

That Oil will intimately diſſolve Lead.

Oil diſſolves Lead.

23. We put two Ounces of crude Lead into an Iron Ladle, and added thereto twelve Ounces of Oil-Olive; then ſetting them over a clear Fire, the Lead evidently melted before the Oil began to boil, and at length the Lead diſappeared, or united and became one with the Oil. By ſtopping the Operation at any time, we could eaſily learn how much of the Lead was diſſolved in the Oil, both by the increaſed Conſiſtence of the Oil, and the Diminution of the Lead.

The Experiment extended.

24. The ſame Experiment may hold alſo of Tin, and of Tin and Lead mixed. How far it is applicable to the other Metals has not been hitherto ſatisfactorily tried. Some have ſuppoſed that Oil will diſſolve Copper and Iron: But it ſhould be carefully examined whether the effect be not owing to an Acid concealed in the Oil; for it is the known Property of Acids to diſſolve theſe Metals. This has been obſerved, that if Oil be well boiled, to get out its aqueous Parts, it is the better fitted to preſerve Utenſils of Iron, Braſs, or Copper, from Ruſt. Whence Marrow is reckoned better for this Purpoſe, than other Fats or Oils more ſubject to harbour aqueous Moiſture. And if a little Ceruſe, or Black Lead, be added in the boiling, the Oil becomes ſtill more proper for this Purpoſe. Now it is the Property of Ceruſe, and black Lead, to drink up Acids; and therefore it may be hence concluded,

that ſome acid Parts, naturally contained in Oils, are the Cauſe of their Ruſting or Diſſolving the Iron, Braſs, or Copper, on which ſuch Oils are laid.

Its Uſes. 25. The Preparation, or Subſtance, obtained in the preſent Experiment, being taken from the Fire at different times of the Operation, makes either a Balſam, a Cement, or a Plaiſter; and ſo is fit for various Uſes. As a Balſam, and a Plaiſter, it is ſerviceable in Chirurgery. As a Cement, it is excellent in Water-Pipes; and being laid upon hot Brick-work, or the like, fits it for holding Water. It alſo ſerves to hold crack'd Glaſſes together, ſo that they ſhall be as firm in the Crack, as in the Sound Parts.

26. But a more phyſical Uſe of the Experiment is, to ſhew the great Affinity which the ſoft and fluid Body of Oils, as a *Menſtruum*, has with the ſolid Bodies of Metals, and how they may mutually, not only diſſolve, but diſguiſe and conceal each other; ſo that Metals ſhall be contained in Bodies where the Eye would never ſuſpect them.

27. The preſent Experiment alſo affords ſome Light in the Doctrine of Solders, or, the Mixtures of metalline Matters, that will run with a leſs Degree of Heat than the Metal propoſed to be ſolder'd, and tenaciouſly lay hold thereof. For Oil, or Greaſe, is an uſeful Thing to facilitate the running of theſe Solders; as we ſee in the Soldering of Lead and Tin, where the Plumber uſes his Tallow, as the Tinman does his Roſin; by means whereof the Solder and the Metal are the better ſoften'd, and in ſome Meaſure diſſolved and incorporated together.

The Relation betwixt Oils and Metals. 28. We deſire that this great Affinity betwixt Oils and Metals may be remember'd; as being of extenſive Conſequence in the Buſineſs of Metals, and more particularly in the ſublimer Metallurgy; where certain Expreſſions, concerning the *Sulphur of Metals* may be underſtood to advantage, by taking them to mean an actually inflammable Subſtance, or Oil.

EXPERIMENT IV.

That innocent and unlikely Subjects may afford powerful Menſtruums, *ſhewn in Bread.*

Bread diſtilled. 29. We took two Pounds of common brown Bread, cut it into ſmall Pieces, and put it into a Glaſs Retort. We placed the Retort in a Sand-Heat, and luting on a Receiver, diſtilled with a moderate Fire, ſo long as any aqueous Liquor came over: at length ſuffering all to cool, we took off the Receiver, and by the Filtre ſeparated the Liquor obtained, to clear it of its Oil. This Liquor we rectified from its Phlegm in *Balneo Mariæ*, and afterwards diſtilled it over again in a Sand-Heat, ſo as to obtain a moderately ſtrong, acid, limpid Liquor, under the name of the rectified Spirit of Bread.

Uſes of the Experiment. 30 In this manner we obtain from common Bread a large Proportion of an aqueous Liquor, mixed with acid Parts, ſo as to be capable of extracting the red Colour out of Coral, or even Garnets. But to procure this Liquor in its greateſt Strength and Perfection, we ſhould make Uſe of Rye Bread, or ſome of the coarſer ſorts.

31. The Experiment being duly proſecuted, affords us the Analyſis of Bread; a Subſtance capable of recruiting and forming all the ſolid Parts of our Bodies. And no wonder, ſince it contains nearly the ſame Principles as animal Matters. For Blood, Fleſh, or Bone, upon their Analyſis, reſolve into Water, Oil, volatile Salt,

and Earth; the whole, by Decoction, making a Kind of mucilaginous, or gelatinous Subſtance with Water: And in the ſame manner Bread boils with Water into a gelatinous or mucilaginous Subſtance, and when diſtilled, reſolves into Water, an acid Spirit, Oil, and Earth. The principal Difference between them is, that Bread affords a volatile *Acid* by Diſtillation, whereas Fleſh, or Blood, affords a volatile *Alkali*. Whence it ſhould ſeem, that there is in the Body a certain Power of Changing the Matter of an *Acid* into that of an *Alkali* *.

Extended.

32. To gain a clearer Information from the preſent Experiment, we could wiſh it were repeated with ſuch Bread as contains no Sea-Salt, which is a common Ingredient in the uſual Kinds of Bread. For Sea-Salt affords a conſiderable Proportion of acid Spirit upon Diſtillation, and this Spirit may have a great Share in diſſolving the Bodies ſuppoſed to be diſſolved by the Spirit of the Bread. But however that Matter may prove, the Experiment ſhews a powerful *Menſtruum* is obtainable from an innocent and unlikely Subject. And the ſame has been found to hold of many other Preparations; as Wine-Vinegar, tartarized Tartar, *&c.* Whence the like Experiments ſhould be tried upon other common Subjects, ſuch as the Yolks and Whites of Eggs; Rennet, Curd, Whey, Milk, Butter-Milk, Cheeſe, Urine, *&c.* in order to diſcover whether ſerviceable *Menſtruums* might not be thus procured.

EXPERIMENT V.

That Quickſilver diſſolves Metals.

Amalgamation of Lead.

33. We melted two Ounces of clean Lead in an Iron Ladle, and in another Ladle we heated

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* See more to this purpoſe in *Lect.* VII.

the ſame Quantity of Quickſilver till it juſt began to fume; then we poured the Quickſilver to the Lead, and ſtirred them both together with an Iron Rod: upon letting them cool, they made a white, hardiſh, homogeneous Maſs; a part of which, being ground with more freſh Quickſilver, readily and intimately mixed therewith.

The Experiment extended, with its Uſes.

34. This Experiment ſucceeds with all the Metals, except Iron; which therefore appears of a leſs mercurial Nature than the reſt. The Operation itſelf is called *Amalgamation*, that is, the intimate Mixing of a Metal with Quickſilver, and is the Foundation of Gilding and Silvering. For an Amalgam of Gold being rubbed upon a well poliſhed Plate of pure Silver, and the Plate afterwards expoſed to ſuch a Degree of Heat as will evaporate the Quickſilver of the Amalgam, the Plate is left gilt. The Caſe is the ſame when Copper is to be ſilver'd. And thus Gold, or Silver, is uniformly diffuſed through the Body of the Quickſilver; whence a ſingle Grain of Gold, Silver, Lead, or Copper, may be divided to an almoſt inconceivable Degree; or ſpread uniformly through a Maſs of a thouſand Pounds Weight of Quickſilver, every the ſmalleſt Particle of which ſhall contain a Quantity of Gold proportionable to the Whole. And hence it appears that Quickſilver is a true *Menſtruum* to all the Metals, except Iron; diſſolving them as perfectly as Water diſſolves Salt.

35. The preſent Experiment alſo ſhews us how Quickſilver may be adulterated with a Proportion of Lead: but the Fraud is eaſily diſcovered, by putting a little Quantity of ſuch debaſed Quickſilver into an Iron Ladle, and exhaling away all the Mercury which will thus leave the Lead behind.

36. We may likewiſe hence underſtand the fraudulent Tricks of ſome pretended Alchemiſts, who feigning an Occaſion for the Uſe of Mercury in their Proceſſes, do beforehand ſecretly diſſolve, or procure to be diſſolved therein, a certain Proportion of Gold or Silver; which not flying off along with the Quickſilver in the Fire, the credulous By-ſtanders are made to believe, that the baſer Metals employed are enriched with the nobler in the Operation. The Inſtances of ſuch Frauds are many, and have brought a great Stain upon the Art of *Alchemy*. But they are eaſily detected, by expoſing a Part of the Operator's Mercury to the Fire; for the Quickſilver going off in fume will leave the Silver and Gold behind.

EXPERIMENT VI.

That Aqua-Fortis, *or Spirit of Nitre, is the* Menſtruum *for Silver*; *and* Aqua-Regia *the* Menſtruum *for Gold.*

Gold and Silver diſſolved.

37. We took two Drachms of the fineſt Silver reduced to Filings, and poured upon it twice its Weight of proof *Aqua-Fortis*; then ſet the containing Glaſs in a gentle Heat, under a Chimney, till the Solution was perfectly made.

38. We took ten Grains of Leaf-Gold, and poured upon it two Drachms of *Aqua-Regia*; then ſet the Glaſs in a Sand Heat to warm thoroughly. After the Gold was diſſolved we added a Grain or two more, till the *Menſtruum* was fully ſaturated, and then decanted the clear yellow Solution. We afterwards put a few Grains of Silver into *Aqua-Regia*, and a few Grains of Gold into *Aqua-Fortis*; and kept the containing Glaſs warm, in the ſame manner as before, but found no Solution enſue in either caſe.

39. Thus we ſee that Gold and Silver are perfectly diſſolved in their reſpective *Menſtruums*, neither of which will touch the other Metal. For if any Gold be contained in the Silver, it will fall to the Bottom of the Solution in the form of a black Powder; and if any Silver be contained in the Gold, it does ſo likewiſe.

Proof-Aqua-Fortis *what.*

40. The *Aqua-Fortis*, for the Solution of Silver ſhould be made *Proof*; that is, it ſhould be capable of diſſolving half a Grain, or a Grain of Silver immediately, without growing in the leaſt turbid; as it would do if it contained any Sea-Salt: in which Caſe it would be a Kind of *Aqua-Regia.*

How made.

41. *Aqua Fortis* is made by diſtilling purified Nitre with calcined Vitriol, or rectified Oil of Vitriol, in a ſtrong Heat, whereby an extremely corroſive acid Liquor is driven over in blood-red Fumes.

Aqua-Regia *what.*

42. *Aqua-Regia* is made by diſſolving a fourth part of Sea-Salt in the *Aqua-Fortis* above mention'd.

Uſes of the Solution of Silver.

43. If the Silver employed in the Solution were abſolutely pure, the Liquor will be pellucid: but if any Alloy, or Copper, remain mixed with it, the Solution will have a bluiſh or greeniſh Caſt. If a Solution of perfectly pure Silver be diluted with fair Water, it will ſtill remain pellucid, without letting any thing precipitate. But if any ſaline Matter be contained in the Water, the whole will now turn thick or milky. The Solution of pure Silver, when properly weaken'd with Water, may be commodiouſly uſed for ſtaining the Skin, or other animal Subſtances, black. And if white, grey, or red Hair be moiſtened with it, the Hair will ſoon become of a beautiful brown, or jet-black Colour. For which purpoſe it may be uſed with Safety, Care being taken not to touch the Skin therewith; for

thus a Blackneſs would be occaſioned, that requires many Days before it goes off again; but it diſappears at length, by the Scarf Skin peeling off, without cauſing any Pain, or leaving any Sore behind.

44. The Solution of pure Silver has an intolerably bitter Taſte; tho' to the Eye it be not diſtinguiſhable from fair Water: In which we have an eminent Inſtance how Metals may lie concealed from the Sight, or remain lodged in unſuſpected Liquors, and thence be introduced inviſibly into other Subſtances. Whence the greater Caution ſhould be uſed with all Pretenders to the Melioration and Tranſmutation of Metals.

45. This Solution of Silver is the Foundation of ſeveral medicinal and chemical Preparations; as the *Vitriol of Silver*, the *Lunar Cauſtic*, the *Silver-Pill*, &c.

The Silver how recoverable.

46. The Silver is recoverable from this Solution, barely by ſuſpending a Copper-Plate therein: For Copper being more eaſily diſſolved by *Aqua-Fortis* than Silver, the Silver is thereby precipitated to the bottom, in the form of a Powder, which being waſhed and melted comes into a metalline Lump again. And this is alſo to be underſtood of the Solution of Gold.

Uſes of the Solution of Gold.

47. But, on the other hand the Solution of Gold is yellow, or gold-coloured, and tinges the Skin purple, as the Solution of Silver ſtains it black. It may be further added, that if the Solution of Gold be precipitated with Salt of Tartar, and the Powder carefully dried, it makes the *Aurum fulminans*, ſo called from the violent Exploſion with which it goes off, when heated beyond a certain Degree *.

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* See hereafter the *Lecture* upon *Pyrotechny*.

EXPERIMENT VII.

The diſſolving Power of the Digeſtor, *an Inſtrument contrived at once to direct the Action of Water, Air, and Heat, in a high Degree, upon a Subject.*

The Structure and Uſe of the Digeſtor. 48. The *Digeſtor* is a ſtrong Veſſel made of Copper, or Iron, and fitted with a cloſe Cover and Screws, ſo as to remain perfectly tight, in a conſiderable Degree of Heat; whilſt Water, common Air, and the Subject of the Operation are contained within.

Ox-Bone ſoften'd. 49. We took a Pound of freſh Ox Bone in a ſingle Piece, with two Quarts of common Water, and leaving a conſiderable Space for the Atmoſpherical Air, we ſcrewed them all up together in the *Digeſtor*, and applied a moderate Degree of Heat to the Bottom thereof, for about a quarter of an Hour, or till a Drop of cold Water, let fall upon the Cover, would evaporate in a very few Seconds of Time: after which letting all cool, we opened the Veſſel, and found the Bone ſoft and tender, ſo as to be cut with a Knife, the Water about it turned to a hard Jelly, and a large Quantity of Fat in a ſolid Cake at the Surface.

Rationale *of the Experiment.* 50. The Effects of this Inſtrument will not appear ſurprizing, if the Forces that act within it be duly conſider'd. For, as we have formerly ſhewed the inſtrumental Efficacy of Fire, Air, and Water to be very great, even when ſeparate, it is no wonder they ſhould act extremely ſtrong upon a Body in conjunction *.

Its Uſes. 51. Hence the *Digeſtor* ſeems, of all the Inſtruments, or Veſſels, hitherto invented, the moſt powerful for increaſing the Action of *Menſtruums.* And if a ſuitable Method could be diſcover'd for ſtrengthening the Engine, ſo as to work ſafely with a very ſtrong Degree of Heat, we might reaſonably expect to perform ſome very extraordinary Operations by its means, in the way of Extraction, Decoction, Tincture, Solution, and perhaps even Deſtruction, or Tranſmutation *a).*

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* See the five preceding Lectures, *paſſim.*

52. But a Courſe of Experiments and Lectures upon this Engine alone, would ſcarce be ſufficient to ſhew and explain its numerous Uſes and Applications for improving the Doctrine of *Menſtruums.* And what Effects the common Solvents, as *Alcohol*, *Oils*, *Aqua-Fortis*, *Mercury*, and Metals themſelves, might have, when aſſiſted by this Engine, is not eaſy to foretel; and indeed it would require much Induſtry and Application to diſcover them.

AXIOMS *and* CANONS.

1. We learn from the preceding Enquiry, that Water is a *Menſtruum* which, of itſelf, diſſolves little more than Salts *b)*; but, being aſſiſted by Acids, diſſolves Earths, and even Metals themſelves *c)*. And hence might be drawn a *general Rule of Practice*, for making Water an almoſt univerſal *Menſtruum.* Thus, by the Addition of a fixed Alkaline Salt, it diſſolves Oil into a Soap; by the Addition of *Alcohol*, it extracts the reſinous Tinctures of Vegetables: and in this Manner it might be proper to run through the different Subjects of the vegetable, animal, and mi-

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a) See Dr. *Papin*'s Treatiſe of this Inſtrument. See alſo the Lord *Bacon*'s Philoſophical Works, *paſſim.*

b) Exp. I. See alſo *Lect.* V.

c) Exp. I, VI.

neral Kingdoms, and form Tables of the ſolutive Powers of Water, ſimple and compounded.

2. That ſuch Tables may be readily formed of the diſſolving Powers of all the known *Menſtruums*, to ſhew by Inſpection, in what Time, in what Proportion, and with what Degree of Heat, all Solvents perform their Action; which being once reduced to a Certainty, would greatly facilitate and improve the Practice of Chemiſtry *a*).

3. That the Power of *Alcohol*, as a *Menſtruum*, is chiefly limited to Roſins and Oils; but, by certain Additions, may be extended, as was ſaid of Water, ſo as to become an almoſt univerſal Solvent *b*). Thus, by the Addition of Water, it becomes Brandy, or Spirit, which extracts many Tinctures that neither pure Water nor pure *Alcohol* will ſeparately extract. Whence we have a good Inſtruction for attempting a new Set of *Menſtruums* by Mixture, or the Compoſition of two or three ſimple Solvents. And if the requiſite Care and Skill were employed in this Matter, many uſeful Diſcoveries might be juſtly expected from it. Indeed, the mixing of two *Menſtruums* may ſometimes deſtroy the Virtue of both: thus Spirit of Nitre and ſimple Water will each of them ſeparately diſſolve the human *Calculus*, but when mixed they will not touch it. This Inſtance however is only particular, and there are a large Number producible on the contrary ſide; which may rationally recommend a farther Proſecution of this Enquiry.

4. That Metals are ſoluble in Oils, and in acid Spirits, ſo as not to be eaſily diſcovered therein *c*). Whence a Rule may be drawn for a prudent Suſpenſion of the Judgment, and a rational Diſ-

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a) *Exp.* I. See alſo *Lect.* V.
b) *Exp.* II.
c) *Exp.* III, VI.

truſt of the Senſes in chemical Operations: And alſo, a Caution againſt being impoſed upon by the vain Pretences of Alchemiſts *a*).

5. That the Power of a *Menſtruum* is not to be judged of by its Innocency with regard to the animal Body. The acid Spirit of Bread is innocent and wholeſome, yet capable of diſſolving Coral and Gems *b*). Pure Oil-Olive will diſſolve Lead and Tin. The White of an Egg, boiled hard, and ſuffer'd to run *per deliquium*, diſſolves the tough Body of Myrrh. The Inſtances of this Kind are extremely numerous. They well deſerve to be collected and tabled, that the Mind may be thereby cured of the Prejudice it has too readily imbibed, as if Corroſives only were Solvents.

6. That the Action of *Menſtruums* depends upon a certain Secret and reciprocal Relation betwixt the Solvent and Solvend, ſcarce cognizable by the direct Senſes, nor hitherto well made out by Inſtances and Induction. Alkali and Acid, Attraction and Repulſion, Sympathy and Antipathy, ſeem rather Words coined to expreſs the Action, than to aſſign the phyſical Cauſes thereof. And hence the Action of new *Menſtruums* cannot be determined, or rationally conjectured, beforehand; becauſe it depends upon a Cauſe not hitherto known.

7. That *Menſtruums* have not their full Action, unleſs reduced to a fluid or ſubtile State *c*). Water in the firm and ſolid Form of Ice does not act on Salts; but they ſoon begin to diſſolve each other upon Contact. Metals do not act on Metals, in the Way of Solution, till they are fuſed: Nor does Sulphur diſſolve Quickſilver, till they are both reduced, either to a fluid or very ſub-

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a) See above, §. 26, 33—36.

b) *Exp.* IV.

c) See the *Lecture*, *paſſim*.

tile State, by Triture, or by Melting. And this appears to be the Caſe in all Inſtances. Whence, in order to promote the Action of *Menſtruums*, we are directed to reduce both the Solvent and Solvend to minute Parts, or as near as poſſible to a fluid State, whether by Heat, Triture, Fuſion, or otherwiſe. And hence appears the phyſical Cauſe of the ſingular Efficacy of Fire, Air, Water, and Trituration in promoting the Action of *Menſtruums* a).

8. That Quickſilver is a true Solvent of Metals, incorporating with them, as Water does with Salts b); by which Means one Metal may be readily united with another, in any Proportion, by ſimple Triture c). And hereby alſo many Operations in the ſublimer Metallurgy are chiefly performed d).

9. That acid Spirits are not, equally, proper *Menſtruums* to all the Metals; thus Spirit of Nitre, tho' it diſſolves the reſt, will not diſſolve Gold e). So neither is Quickſilver itſelf a proper *Menſtruum* to them all; for it does not diſſolve Iron f). And the true phyſical Reaſon hereof ſeems not hitherto ſatisfactorily diſcovered, tho' numerous Conjectures have been made about it

10. That all the Bodies in nature may become *Menſtruums* to one another, each of them being, by ſome Means or other, capable of having their ſmall Parts uniformly interpoſed betwixt the ſmall Parts of any of the reſt. Thus even Metals may, by Art, be made to diſſolve in Water; as we evidently ſee from numerous Solutions of Metals

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a) See the five preceding Lectures, *paſſim*.

b) *Exp.* I and V. See alſo *Lect.* V.

c) See above, §. 33, 34.

d) See hereafter the Lectures on *Mineralogy* and *Metallurgy*.

e) See *Exp.* VI.

f) *Exp.* V.

in acid Spirits: theſe Spirits being no more than Water charged with the fine or more volatile Parts of Salts.

11. That the Cauſe of Solution commonly aſſigned, *viz.* the Admiſſion of the fine Particles of one Body into the Pores of another, whoſe Figure is fitted for their Reception, is not juſt or adequate, but hypothetical and ill-preſumed, ſince we find that ſome Bodies will uniformly diſſolve their own Quantity of others *; as Water does of *Epſom* Salt, *Alcohol* of eſſential Oils, *Mercury* of Metals, one Metal of another, *&c.*; whereas the Sum of the Pores, or Vacuities, of every Body muſt be neceſſarily leſs than the Body itſelf; and conſequently thoſe Pores cannot receive a Quantity of Matter equal to the Body wherein they exiſt: for this were to make the contained Matter bigger than the Pores that contain it.

12. That the diſſolving Power of Water may be immenſely increaſed by means of the *Digeſtor*, an Inſtrument not hitherto introduced into Chemiſtry, tho' probably applicable to the great Improvement of that Art; as being a Contrivance, which at once determines the Action of a Solvent upon the Solvend, with all the Advantages of Heat, Air, and Water, briſkly agitated and confined, under a State of Compreſſure, ſo as to make them act like different Sets of Stampers upon the Matter to be changed. For this Engine at once employs all the four Agents required to make the greateſt Part of *Menſtruums* act with Advantage; *viz.* Fire, Air, Water, and Triture. Whence there are ſome ſolid Grounds of Hope, that it may, under a proper Regulation, greatly contribute to the Improvement of Chemiſtry, Natural Philoſophy, and Arts.

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* *Exp.* I. II. V.

13 Upon the whole it ſhould ſeem, that many deſirable Improvements are derivable to Arts from an Improvement in the Buſineſs of *Menſtruums* *. The Diſcovery of that common *Menſtruum*, *Aqua-Fortis*, introduced the Art of Aſſaying, and the Scarlet Dye. That of *Alcohol* introduced the Arts of Varniſhing and Japanning, numerous Pigments for Painters, Colours for Dyers, Tan-Liquors for Tanners, the Staining of Bone, Horn, Ivory, Marble, various Kinds of Ink, Tinctures, and Solutions, in Medicine, Chemiſtry, and other Arts, have all reſulted from the Diſcovery of *Menſtruums*. Yet the Subject ſeems almoſt as new and rich as ever; ſo that numerous other Diſcoveries, of the ſame Kind, would not exhauſt it.

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* See the whole Enquiry, *paſſim*.

LECTURE VII.

CONTAINING

An Enquiry into the Nature, Office, and Effects of Fermentation *and* Putrefaction, *in the Vegetable, Animal, and Mineral Kingdoms.*

1. THE Purport of this Lecture is to enquire into the Nature, Effects, and Uſes of Fermentation and Putrefaction, as they are the natural Means of converting one Body into another; in order to acquire a farther Knowledge in the *Chemiſtry of Nature*, and thence derive ſome ſerviceable Rules for the Improvement of *Philoſophical Chemiſtry*. *The Subject.*

2. But as the Subjects of Fermentation and Putrefaction ſeem to have been imperfectly treated by Authors, and to lie buried, as it were, in Obſcurity, we ſhall endeavour to let ſome Light in upon them by particular Experiments, and our Explanations of them; ſo as to ſhew the Steps of *Nature* and *Art*, in conducting and regulating theſe *capital Operations*, for altering and changing vegetable, animal, and mineral Subjects in the three grand Regions of Nature, *viz.* the *Earth*, *Ocean* and *Atmoſphere*.

3. That we may proceed the more clearly, we ſhall begin with *Fermentation* in vegetable Subjects, and trace it thro' all its Stages; till at length it terminates in *Putrefaction*, which reduces vegetable Subjects to an animal Nature. We ſhall next conſider the ſimilar Proceſs in animal *TheOrder.*

Subjects; and *laſtly*, examine whether any Thing of the ſame Kind obtains among Minerals.

I.

To begin with vegetable Subjects:

EXPERIMENT I.

The Nature and Uſes of vinous Fermentation; or the Way of changing the natural Juices of Vegetables into Wines.

Wine made from Raiſins.

4. We took a Quarter of an hundred of whole, or unbruiſed, *Malaga* Raiſins, and put to them ſeven Gallons of cold Spring-Water, in a wooden Veſſel or Caſk, which we ſet looſely cover'd in a warm Place, that the Contents might ferment for ſome Weeks. We found that the Water ſoaked thro' the Skins of the Raiſins, diſſolved their internal ſweet or ſaccharine Subſtance, and became impregnated therewith, as a *Menſtruum*; that the Liquor manifeſted an internal Struggle and Commotion of its Particles, throwing up numerous ſmall Bubbles to the Surface, with a conſiderable hiſſing Noiſe; and that when the Fermentation was finiſhed, the Liquor was become an actual new Wine, as appear'd by the Taſte, Smell and Effects, having depoſited a large Quantity of groſs, earthy Sediment, called Lees, at the Bottom, different from the Huſks, or Skins, and Stones of the Raiſins.

The Experiment extended.

5. This Experiment is univerſal, or ſhews the general Manner of making Wines, and all other ſpirituous potable Liquors, or Drinks, by Fermentation. For, with a ſlight Change of Circumſtances, it is applicable to the Brewing of Beer from Malt; Mead or Metheglin from Honey; Cyder and Perry from Apples and Pears

reſpectively; artificial, or made Wines, as they are vulgarly called, from Cherries, Gooſeberries, Currants, Elder Berries, Blackberries, Plumbs, Oranges, or other Fruit; alſo, from the Tappings of certain Trees, as the Birch, the Maple, the Sycamore, *&c.* and more eminently from the Juice of the Sugar Cane, Treacle, or common Sugar and Water. For any of theſe vegetable Juices, being duly fermented, afford as real and perfect Wine, according to their ſeveral Natures, as the richeſt Grapes of the beſt Wine-Countries.

And applied; with its Uſes.

6. To bring any of theſe Juices into a ſound Wine, the Rule is to evaporate them, if they are naturally too thin, till they become of equal Richneſs with the Juice of the Grape, in Wine-Countries and in good Wine-Years. This may commodiouſly be done, by Means of the common Water-Poiſe *, which ſhews the Strength or Richneſs of Solutions to the Eye. And in general, any vegetable Juice, or Solution, is accounted ſufficiently rich for making a ſtrong Wine, when it will ſupport a new laid Egg on its Surface.

7. The Wines made at preſent in *England* lie under a Diſrepute; the Reaſon whereof ſeems chiefly owing, *firſt*, to the inartificial Manner wherein they are uſually prepared, and, *ſecondly*, to a certain Rumour ſpread about them, as if they were unwholeſome, crude, indigeſtible, too luſcious, too tart or griping, and apt to occaſion the Head ach, *&c.*

8. Thoſe, who have never been in Wine Countries, nor otherwiſe made themſelves acquainted with the Nature and common Preparation of

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* See *Lect.* V. *Exp.* VI.

Wines proceed in their Judgment of them according to Report, popular Notions, and the immediate Information of the Senſes. Thus, for Inſtance, Red-Port Wines, to pleaſe the common Palate, muſt be bright, deep-colour'd, rough, rich and racy, two or three Years old, *&c.* and when this or any other Notion comes once to be eſtabliſhed as the *Criterion* of Wine, the Cooper is thereby directed how to hit the general Taſte, and make a ſaleable Commodity.

Theory. 9. Upon the ſame Foundation *Philoſophical Chemiſtry* inſtructs us to imitate the Wine-Cooper, and from almoſt any ſweet and tart vegetable Juice, to make ſaleable Wines, even Sacks, Mountains, Sherries, or Ports; all of which by the way, are uſually mixed Liquors, tho' the Baſis of them all is the Juice of the Grape.

10. This Juice of the Grape being chemically examin'd and conſidered, proves to be no more than a large Proportion of real Sugar diſſolved in Water, with the Addition only of a certain Flavour in the Juice of the Grape, according to the Nature of the Vine. Whence we lay it down as an *Axiom*, and the Reſult of a careful Enquiry, that a *ſaccharine Subſtance is the Baſis of Wines.* For Sugar is not peculiar to the Sugar-Cane, but obtainable alſo from Grapes; and accordingly we often find large Grains thereof in dried Raiſins; particularly in thoſe of *Malaga*, that have lain for ſometime, and ſweated together, by which Means they run into Candy, a ſaccharine Efflореſcence, and actual Grains of Sugar. So again, it is cuſtomary in *France* to evaporate the Juice of the Grape till it becomes coagulable in the Cold, and in this State to uſe it as a moiſt Sugar, under the Name of *Reſiné.* And the ſame Thing is to be underſtood as practicable in Malt,

or Wort, and the ſweet Juices of all Vegetables that afford a Wine by Fermentation *.

11. Hence therefore we may derive a Set of Rules, for boiling down, or otherwiſe procuring the eſſential Matter of Wines in a ſmall Bulk, and preſerving it ſound and ſerviceable for many Years, in order to the Making of all Kinds of Wines, Vinegars, and Brandies, even in Countries where no Vines grow. And this Diſcovery alſo affords great Light into the true Nature and Uſes of *vinous and acetous Fermentation.* *Rules.*

12. To illuſtrate and confirm this Diſcovery by an Example, upon the Footing of the preſent Experiment: Take two hundred Weight and a half of double refined Sugar; put it into a Pipe, or Wine Veſſel of two Hogſheads; fill the Veſſel within four Gallons of the Top with pure Spring-Water; ſet in a warm Place, or Wine-Vault; and three or four Pounds of freſh Ale-Yeaſt, or rather of new Wine-Yeaſt; and the Liquor in a few Months time will ferment into a ſound, colourleſs, and flavourleſs Wine, and remain ſuſceptible of any Colour or Flavour at Pleaſure; ſo as with the Stain called *Turnſol*, to be made of the true Claret-Colour; and with a little eſſential vegetable Oil, of any particular Flavour required. And this is here deliver'd as an Experiment that ſucceeds to great Perfection; ſo as to ſhew a rational and practicable Method of producing Wines in the Sugar Colonies, or elſewhere, that ſhall rival thoſe of *France*, *Italy*, or *Spain*; and if the Nature of Fermentation be well underſtood, the Proceſs may be greatly ſhortened in point of Time, as well as improved in other Reſpects. *Practice.*

13. And ſo much for the Uſe of our preſent Experiment, with regard to Trade, and Oeconomy; *Uſes to Trade.*

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* See an Eſſay upon the Art of *Brewing* and *Diſtillation.* See alſo hereafter, *Lect. XI. paſſim.*

nomy. Its philoſophical Uſes are no leſs conſiderable. And firſt, it ſhews that the proper fermenting Matter of every fermentable Subject is but ſmall, compared with the Quantity of Wine it affords. Thus, for Example, we ſee that four Pounds of Raiſins may be diluted, and fermented, with eight Pounds of Water, into what is accounted a tolerably ſtrong Wine. And yet even Raiſins themſelves contain a large Proportion of Water, beſides their directly ſaccharine Subſtance; which ſaccharine Subſtance is reducible to a dry Form, as we find in Sugar. And whoever would thoroughly enquire into the Nature, the Uſes, and the Means of improving *vinous* and *acetous* Fermentation, cannot perhaps do better than to chuſe Sugar for his Subject; a chemical Analyſis whereof will ſhew the Principles neceſſarily required in this Operation. Theſe Principles appear to be an acid Salt, an Oil, and Earth ſo united together, as to be capable of diſſolving perfectly in Water.

To Philoſophy. 14. Hence we alſo ſee the phyſical Cauſe of the fermentable Nature of River-Waters; which being kept in cloſe Caſks have been obſerved to ferment, and their Vapor, or Spirit, to take Fire at the Approach of a Candle. For much vegetable Matter, as Leaves, Graſs, the Juices of Plants, *&c.* being by the Rains waſhed down into Rivers, ſuch vegetable Matters muſt neceſſarily there run into a fermenting State, as Raiſins do by the Addition of Water; the running or fluxible State of the Rivers being no Hindrance to this fermentative Motion, after it is once begun by Stagnation. For we ſee that Beer and new Wine will ferment afreſh upon being ſhook, and carried upon Drays, or Carts.

15. All fermentable Bodies do not require *Ferments* to begin their Motion of Fermentation.

Raiſins, we ſee, require none; much leſs does the freſh expreſſed Juice of the Grape, or other vegetable Juices, in the Summer-Seaſon, or in a warm Air. But all ſweet vegetable Juices, that have felt much of the Fire, as Treacle, or Wort high boiled, Rob of Malt, Rob of Elder, or the like, uſually require a conſiderable Proportion of a vinous Ferment to make them work. In general, Ferments are no more than Matters already in the Act of Fermentation, or that ſoon run into this Act: Of the firſt Kind are the Flowers of Wine, Yeaſt, fermenting Beer, or fermenting Wine, *&c.* and of the ſecond, are the new expreſſed vegetable Juices of Summer-Fruits, *&c.*

16. Water, we find, is abſolutely neceſſary to begin and procure a fermentative Motion in vegetable Subſtances. For Raiſins, or Sugar, being kept dry, will never ferment. And this holds univerſally of all the Subjects of *vinous* and *acetous Fermentation.* Whence Water is an Inſtrument that muſt be neceſſarily employed in theſe Kinds of Fermentation, whether natural, or artificial *a*).

17. As the Water which naturally, and in large Quantities, perſpires from the Surface of Vegetables, eſpecially in hot Climates, does not go off pure, but carries along with it a conſiderable Proportion of fermentable Matter into the Atmoſphere *b*), there may be an actually vinous Fermentation begun and carried on in certain Parts of that Region, eſpecially where the Winds are ſtill, or the Air ſtagnant. And what phyſical Effects and Uſes this Fermentation in the Atmoſphere may have, ſcarce ſeems to have been conſider'd; nor ſhould they be raſhly judged of, till a more thorough Enquiry is made. At

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a) See *Lect.* I. III. V. *paſſim.*

b) See *Lect.* V.

Schiedam in *Holland*, a larger Quantity of inflammable Spirit is ſaid to be obtained from Malt, than in any other Place, where there are fewer Malt-Diſtillers. This is probably owing to the Air of that Place being impregnated with the fermenting Vapours, that continually exhale from their numerous fermenting Backs and Stills. And the ſame is found to hold proportionably of Wines fermented in large Vaults or Cellars, where many Caſks of Wine are at once, or ſucceſſively, ſet to work.

18. Warmth, with the free Admiſſion of the external Air, is neceſſary to expedite the Action of vinous Fermentation; for if our Raiſins and Water were to ſtand either in a very cold Place, or to be kept entirely from the Acceſs of the common atmoſpherical Air, either no Fermentation, or a very weak and ſlow one, would enſue; as has been experienced.

19. The Lees remaining at the Bottom of the Caſk, in our preſent Experiment, are, if uſed freſh, a true Kind of *Ferment*, that will ſet any leſs fermentable Subject at work, and determine its Fermentation to the vinous Kind. They contain a large Proportion of eſſential Oil, and ſome Tartar. And hence we ſee that vinous Fermentation conſiſts, *firſt*, in an inteſtine Struggle or Commotion of the Fluid; and, *ſecondly*, in a Separation of a groſſer Part, which did not appear in that Form before.

EXPERIMENT II.

The Nature, Effects, and Uſe of acetous Fermentation; or the Method of turning vegetable Matters into Vinegar.

Vinegar made. 20. We took the Skins of the Raiſins, and the Sediment left behind, after a Wine was made in the manner of the preceding Experiment, and poured three or four times their Quantity of boiling Water upon them, ſo as to make a thin aqueous Mixture. Then we ſet the containing Caſk, looſely cover'd, in a warmer Place than was uſed for the Wine, and found the Liquor, in a few Weeks time, became a clear and ſound Vinegar; which being drawn off from its Sediment, and preſerved in another Caſk, well ſtopped, continued long perfect and fit for Uſe.

The Experiment extended.

21. This Experiment ſhews us a cheap and ready Way of making Vinegar from refuſe Materials; ſuch as the Huſks of Grapes, decayed Raiſins, the Lees of Wine, Grounds of Ale, Beer, *&c.* which are frequently thrown away as uſeleſs. Thus in many Wine-Countries, the *Marc*, Rape, or dry Preſſings of the Grapes are thrown in heaps, and ſuffered to putrefy unregarded; tho' capable of affording as good Vinegar, as the Wine itſelf would make. In ſome places they bury Copper-Plates in theſe Huſks, in order to make Verdigreaſe: but this Practice ſeems chiefly confined to the Southern Parts of *France.* Our preſent Experiment ſhews us how to convert them to another Uſe; and the Direction extends to all the Matters that have once undergone, or are fit to undergo, a vinous Fermentation; for all ſuch Matters will afford Vinegar. Thus all our Summer-Fruits in *England*, even Black-berries; all the refuſe Waſhings of a Sugar-Houſe, Cyder-Preſſings, or the like, will make Vinegar, by means of Water, the open Air, and Warmth.

The Proceſs phyſically conſider'd.

22. The whole Proceſs, whereby this Change is effected, deſerves to be attentively conſider'd. And firſt, the Liquor to be thus changed, being kept warmer than in vinous Fermentation, in a few days begins to grow thick or turbid, and without throwing up Bubbles, or making

any conſiderable Tumult, as happens in vinous Fermentation, depoſites a copious Sediment. The Effect of this Separation begins to appear firſt on the Surface of the Liquor, which gathers a white Skin that daily increaſes in Thickneſs, till at length it becomes like Leather; and now, if it be continued longer in this State, the Skin turns blue, or green, and would at laſt grow ſolid, and then putrefy: therefore in keeping down this Skin as it grows, and thruſting it gently to the Bottom of the Veſſel, conſiſts much of the Art of Vinegar-making, eſpecially from Malt.

Larger Obſervation. 23. It is to be particularly obſerved, that, if the Wine of our firſt Experiment were not bunged down when arrived at its vinous State, but ſuffer'd ſtill to remain open and expoſed to a warm Air, it would ſpontaneouſly become Vinegar; and the ſooner, if a ſomewhat greater Degree of Heat, than ſerved for the Making of Wine, were employed. Whence we might have uſed the Wine of our firſt Experiment for this Purpoſe, inſtead of adding Water to the Huſks and Sediment, or Lees; but we choſe the latter Way, to ſhew that even ſuch refuſe Matters will afford Vinegar; and again, to intimate how far the Art of Vinegar-making may be ſtill improved, both in *England* where they brew a Wort from Malt, and in ſome Wine-Countries where they make their beſt Wines into Vinegars.

24. What we would chiefly obſerve, for the preſent, is, that *acetous Fermentation* requires a ſtronger Heat than the *vinous*; and that Wines having once finiſhed their Fermentation, as Wines, do not naturally ſtop there; but, unleſs prevented by the Care of the Operator, proceed directly on to *Vinegars*; where again they make

no Stop; but, unleſs prevented here alſo, ſpontaneouſly go on to Vappidity, Ropineſs, Mouldineſs, and Putrefaction. From which larger Obſervation we would deduce this Axiom: That, to ſpeak philoſophically, *the Intention or Tendency of Nature is, to proceed from the very Beginning of vinous Fermentation, directly, in one continued Series, to Putrefaction, and thence again to a new Generation*; which appears to be the grand Circle wherein all natural Things are moved, and all the Phyſical, or rather Chemical, Phænomena of the Globe produced.

25. And hence we ſee how, by the Interpoſition of Man, this general Proceſs of Nature may be ſtopped at different Periods, with different Views; ſo as to procure to ourſelves Wines, Vinegars, and, as will appear hereafter, * particular Salts and Oils.

Corollaries.

26. Another Corollary from the larger Obſervation above laid down, is, That the Word *Fermentation* has been uſually applied to ſignify only a ſmall Part of this grand Operation of Nature. Thus one limits the Word to the Production of Wines; another, to the Production of Wines and Vinegars; and ſome would diſtinguiſh it from *Putrefaction*: whereas either the Term *Fermentation*, or ſome other, ſhould be made general, and denote the *Genus*, or *univerſal Operation*, whereof *Vinification*, *Acetification*, and *Putrefaction*, are only Species. At leaſt we ſhould thus attempt to follow and expreſs Nature, in the Facts that are obſerved, and not proceed, in an arbitrary, narrow, or inadequate Manner, to impoſe Terms, and dreſs out Nature according to our particular Hypotheſes and Conceits. But the Obſervation itſelf, on which

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* See below, *Exp.* VI. VII.

this Doctrine is founded, being of moment to the right Underſtanding of the whole Affair of Fermentation and Putrefaction, we proceed to illuſtrate and confirm the laſt Part of it by an Experiment, as the two former Parts have been already *a*).

EXPERIMENT III.

That Wines and Vinegars, or all fermented vegetable Juices, have a natural Tendency to Putrefaction.

Vappidity and Putrefaction ſucceed Fermentation.

27. We took a Gallon of thick, muddy Vinegar, produced after the Manner of our ſecond Experiment, and letting it ſtand open, in a hotter Place than was required to make it Vinegar, it became in a few days a vappid, nauſeous, and putrefied Liquor, throwing up a large Quantity of a dry powdery Subſtance to the Top, and depoſiting a leſs Quantity of a groſſer Matter at the Bottom; ſoon after which the Body of the Liquor became clear again.

28. We might ſhorten the preſent Experiment, and ſave the Trouble of making either a Wine, or a Vinegar, to ſhew it. For if a Quantity of *Muſt* were ſet in an open Veſſel, in a hot Stove-Room, where the Air had free Acceſs, the Work would ſoon be performed, and the putrified Liquor be produced almoſt at once, without ſtopping at the State either of Wine or Vinegar; according to the larger Obſervation deliver'd above *b*).

Phyſical Uſe of the Experiment.

29. The preſent Experiment has a conſiderable philoſophical Uſe, as affording Light to the Underſtanding, and leading us far into a Knowledge of our Subject. And (1.) it gives us the phyſical Reaſon why Wines and Vinegars,

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a) See *Exp.* I. II.

b) §. 24, 26.

unleſs made exceeding ſtrong, will not keep, but corrupt and putrefy, in hot Countries. For the Heat being there ſo great, as to keep the lighter feculent Parts of thoſe Liquors ſuſpended for ſome time in the Body of the Liquor, Corruption (which proceeds from a tumultuary Motion of all the different Parts of a compound Body together *a*), neceſſarily enſues.

Practical Oeconomical Uſes.

30. (2.) Hence alſo we learn the phyſical Reaſon why Wines and Vinegars require to be racked from their Lees, in order to preſerve them ſound, or keep them from running into Putrefaction, to which we find they are ſtrongly inclined; the Tendency of Nature being ever conſtant in urging them to that State. And the Caſe appears to be much the ſame in animal, and even mineral Subſtances; as we ſhall ſee hereafter *b*).

31. (3). This Experiment, therefore, furniſhes us with a Rule for preſerving vegetable Liquors from the laſt Stage of Fermentation, that is, Putrefaction or Corruption; *viz.* by firſt clarifying, and afterwards ſecuring and defending them from the open Air, and too much Heat. Thus, for example, we can preſerve the natural Juices of Quinces, Oranges, Lemons, Plants, *&c.* ſound and uncorrupt, by firſt clearing them of their groſſer Parts by the Filtre; or in ſome Caſes by Boiling and common Straining; then putting them up in Glaſſes, pouring Oil on the Top, and ſetting them in a cool Place. And in the ſame Manner we find ſome of the more delicate and curious Wines are long preſerved ſound and ſprightly: for the groſſer Feculencies being firſt removed, the Oil poured on the Top prevents the external Air from entering; and by keeping the Glaſſes

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a) See §. 27. and hereafter *Exp.* VI. and VII. See alſo the Lord *Bacon's Sylva Sylvarum paſſim.*

b) *Exp.* VII. VIII.

from the Sun, or open Day, too much Heat does not come at them.

Phyſical and Chemical Uſe.

32. (4) It is here remarkable, what a large Quantity of ſolid, earthy Matter is naturally contained in all fermentable Liquors. Thus, if a pellucid Solution of the fineſt Sugar in Water be expoſed to vinous Fermentation, it ſoon grows turbid, throws an earthy Skin to the Top, and depoſites much terreſtrial Matter at the Bottom in the Form of Lees. If the Wine be now drawn off clear and expoſed to acetous Fermentation, here again it throws off much terreſtrial Matter, both in the Form of a Skin at Top, and of Lees at the Bottom. Thirdly, if tranſparent Vinegar be expoſed to putrefactive Fermentation, here again it ſeparates a conſiderable Quantity of Earth, both at the Bottom and at Top. All which ſhews that the Separation of a groſs Matter is eſſential to theſe ſeveral kinds of Fermentation, and that a copious Earth may lie concealed in fermentable Juices, and tranſparent Fluids, till it finds an Occaſion of manifeſting itſelf to the Senſes.

The Changes produced by Fermentation.

33. Before we proceed to animal and mineral Fermentation, it is proper to examine what are the Changes wrought upon vegetable Subjects by vinous and acetous Fermentation. This we may find, in ſome Meaſure, by comparing Muſt, or a bare Solution of Raiſins in Water, with the Wine and Vinegar which the ſame Muſt, or Raiſins and Water afford, in Vinification and Acetification; and in this Light they may be compared by the bare Uſe of the Senſes: but their internal and eſſential Differences will better appear by a chemical Analyſis, or Diſtillation.

34. Muſt, or a Solution of Raiſins in Water, which makes a Kind of *Muſt* correſponding to the natural Juice of the Grape, is a ſweet, clammy

my and ſomewhat odorous Fluid, which being committed to Diſtillation affords not the leaſt inflammable Spirit. But after having paſſed thro' the Courſe of vinous Fermentation, it acquires ſeveral Properties it had not before. For example: it is more tranſparent and thin; loſes of its Sweetneſs; has ſome Degree of Acidity and Roughneſs; proves more odorous, and affords a large Proportion of *inflammable Spirit*; as appears by the following Experiment.

EXPERIMENT IV.

That vinous Fermentation produces an inflammable Spirit.

Inflammable Spirit obtained.

35. We took three Gallons of new Wine, procured from Raiſins and Water in the manner of our firſt Experiment, and committed it to the Alembic or Still, which being made to work gently, till the Liquor that came over, being thrown upon the hot Still-Head, would no longer take Fire by applying the Flame of a Candle to the riſing Vapour, we thus obtained a conſiderable Proportion of *Brandy*, and a weaker *Spirit*.

Uſe of the Experiment.

36. This Experiment ſhews us the common Method of making Brandies in Wine-Countries, or a Spirit from Malt, Melaſſes, Cyder, *&c.* in others. For the fineſt *French* and *Rheniſh* Brandies, the Rums and the Arracks of the *Indies*, are obtained in the Manner of this Experiment; all of them being uſually diſtilled a ſecond time over, and *made up*, as they call it, with Water, or the weak aqueous Liquor of the ſecond Running, as in our preſent Experiment, to a certain Strength, or ſuppoſed Standard, termed ſaleable *Proof.*

Proof in Spirits what.

37. This *Proof* is judged of by the Head, or Crown of Bubbles, riſing upon the Surface of the Liquor when ſhook in a long ſlender Vial, and by the Manner wherein theſe Bubbles vaniſh. For if they are too large and vaniſh too ſoon, the Spirit is deemed above *Proof*; if too ſmall, and they go off too ſoon, it is ſaid to be below *Proof*. But this is a fallacious Method of Judging; becauſe there are certain known Ways of making a Spirit bear this Trial, when it is in Reality either above or below Proof. For the proper Meaning of the Word is, that a Proof-Spirit ſhould contain about one half Water, and the other half Alcohol *a)*.

Philoſophical Uſe.

38. The philoſophical Uſe of the Experiment is to ſhew, that an inflammable Spirit is produced by the Action of vinous Fermentation, from a vegetable Subject and Water, wherein no Signs of any ſuch Spirit before appeared. Inſomuch that this may be juſtly eſteemed the Criterion, or inſeparable Effect, of *vinous Fermentation.*

Spirit of Wine how btained.

39. The Ways of obtaining this inflammable Spirit, to the beſt Advantage, will be conſidered hereafter *b)*. In the mean time it may be obſerved, that this Spirit being rediſtilled, ſo as to deprive it totally of its aqueous Part, is the *Spirit of Wine*, or Alcohol, whoſe diſſolving Power was ſhewn, in the laſt Lecture upon *Menſtruums c)*; and this Method is the only one that is known of procuring it. For no Subjects but thoſe of the vegetable Kingdom are found to af-

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a) See this Matter farther explained in *Lect.* XII. *Exp.* IV. See alſo *Lect.* I. *Exp.* VII.

b) Lect. XI. and XII.

c) See *Lect.* VI. *Exp.* II.

ford it; and that only by means of a previous *vinous Fermentation.*

40. It ſhould likewiſe be obſerved, that this *Alcohol* is one of the moſt eſſential Parts of Wine; ſo that, when it is withdrawn, the Wine loſes its Nature; as we ſee by the Remains of the preſent Experiment. And when properly uſed, it is a certain Remedy for moſt Diſeaſes incident to Wines; as keeping them ſound and free from Corruption. Whence we have another Rule for preſerving vegetable and animal Subſtances from Putrefaction. For this Liquor proves a kind of Balſam to them all, and is accordingly uſed, with Succeſs, for preſerving even animal Subſtances; as we ſee in anatomical Preparations, *&c.* *The Uſe of the Spirit to Wine.*

EXPERIMENT V.

That acetous Fermentation aboliſhes the inflammable Spirit produced by vinous Fermentation.

41. We put a Quart of ſharp Vinegar into a Glaſs Retort, and diſtilled, in a Sand-Heat, with Degrees of Fire, into a Glaſs Receiver, but found not the leaſt inflammable Spirit come over; only an acid aqueous Liquor, commonly called *diſtilled Vinegar*; which, inſtead of burning, quenches Fire. *Vinegar yields no Alcohol*

42. Hence it appears, that acetous Fermentation has a very different Effect from the vinous; and that the inflammable Spirit produced in the former, is either concealed, altered, exhaled, deſtroyed, or ſome Way aboliſhed, in the latter. A part of this Spirit is unqueſtionably exhaled by the Heat employed in Acetification; yet Part alſo remains behind under a different Modification, ſo as to be recovered by Art in an inflammable Form; as we find by diſtilling the *Sugar of* *Uſe of the Experiment.*

Lead, which is only Lead diſſolved in Spirit of Vinegar.

43. Our Experiment affords us a Criterion of acetous Fermentation, as before we had of the vinous. For if an acid uninflammable Liquor comes firſt over by Diſtillation from a vegetable Subject, previouſly fermented, this will determine that Fermentation to have been of the acetous Kind.

44. Thus, therefore, we are plainly led to allow of two very different kinds of Fermentation, in the ſame vegetable Subject; and we conceive that ſome other Species may be found upon due Enquiry.

EXPERIMENT VI.

That vegetable Matters turn of an animal Nature by a hot Fermentation, or Putrefaction.

Putrefaction in Vegetables. 45 We took a large Quantity of freſh, green Cabbage-Leaves, and preſſed them hard down with Weights in an open Tub, bored full of Holes on the Sides and ſet in a warm Place. By ſtanding in this State for ſome Days, the Leaves conceived a Heat in the middle, which ſpread to the more external Parts, till at length nearly the whole was converted into a pappy, putrefied Subſtance, whoſe Conſiſtence would not well ſuffer it to ſeparate into a thicker and a thinner Part. This Subſtance being diſtilled in a Glaſs Retort, afforded the ſame Kind of volatile Salt and Oil, as if it had been an animal Subſtance

The Experiment extended. 46. This Experiment is general, and ſucceeds alike in all tender, juicy, vegetable Subjects; ſo that both the acid and alkaline Tribe of Plants, the ſweet and the bitter, the aſtringent, and emollient, *&c.* reſolve into this ſame pappy, putrefied Subſtance. We obſerve it alſo in Hay that is ſtacked wet; in Horſe-litter thrown on Heaps; in the Grape-Huſks, or Apple-Pumice, after preſſing for Wine or Cyder; and the larger the Heap, and the greater Weight the Matter ſuſtains, the greater the Heat; provided the Acceſs of the Air be not prevented.

In Uſe. 47. Hence we ſee the Way employed by Nature for changing all *vegetable* into *animal Subſtances*, or of reducing the Matters of both Kingdoms to a Similarity; ſo that the one may be uſed for ſeveral Purpoſes inſtead of the other. And thus Nature annually makes large Quantities of Compoſt, from the refuſe Weeds, Leaves, Traſh of the Fields, Woods, and Gardens; for this vegetable Matter thus putrefying, and becoming ſoft and pulpy, is eaſily diluted by the falling Rains, and thence diſperſed over the Face of a Field, and carried into the Pores of the Earth. And thus the Chemiſt may, by Diſtillation from ſuch putrefied vegetable Subjects, procure volatile Salts and volatile Spirits, hardly to be diſtinguiſhed from thoſe of Hartſhorn, *&c.* at leaſt the volatile Salt and Spirit ſo obtained might ſerve together with Sea-Salt, for making of Sal-Ammoniac *a)*. For it appears that the Matter of the fixed Salt in Vegetables is, by this Operation, truly volatilized. Whence not a Grain of fixed Salt can be procured from the largeſt Quantity of this putrefied Matter, provided the Operation were compleatly performed.

In Trade. 48. This Experiment has various Uſes, not only in Trades, but alſo in natural Philoſophy and Medicine. And firſt, it ſhews an artificial as well as natural Method of converting any, or all of the different Subjects of the vegetable

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a) See *Lect.* XX. *Exp.* I.

Tribe into the ſame undiſtinguiſhable Subſtance, totally deſtroying all the ſpecific Differences which before diſcriminated that great Variety. And the ſame Obſervation reaches alſo to animal Bodies, as we ſhall ſee hereafter *.

In the animal Oeconomy.

49. It alſo throws conſiderable Light upon the Proceſs of animal Digeſtion, as performed in the Stomach and Inteſtines; it ſhews us the Nature of Gangrenes, Mortifications, and carious Bones in the Body; and the phyſical Reaſon why no fixed Salt is found in the Blood, Bones, or Fleſh: All which Particulars may be farther illuſtrated and confirmed, by conſidering the like Proceſs in an animal Subject.

II

EXPERIMENT VII.

That animal Bodies naturally undergo a Fermentation, or Putrefaction, after Death.

Animal Putrefaction.

50. If any large animal Body, as that of a Horſe or a Dog, for example, be expoſed in a dead State to the open Air and the Summer's Sun, it begins in a few Days to ſwell, purge, and emit a nauſeous Stench. At length the Form of the Carcaſs is deſtroyed by the Commotion, and reſolved into a putrid, fetid, ſtercoraceous Matter; a large Part in the mean Time flying off into the Air, ſo as to leave but a ſmall Proportion of a mucilaginous, pappy Subſtance, which ſoon grows dry, or turns to a Kind of Earth. But a Quantity of this Matter being collected before it grows dry, and diſtilled, it is ſaid to afford the burning *Phoſphorus*, as putrefied Urine is known to do.

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* *Exp.* VII.

51. This Experiment or Obſervation is univerſal, and holds equally of Birds, Beaſts, and Fiſh. Whence Rivers, the Ocean, and the Atmoſphere itſelf, muſt neceſſarily be impregnated with fermenting, putrefying, and putrefied Particles, which mixing with other Matters, and being diſperſed through the immenſe Bodies of thoſe Fluids, they undergo therein ſuch Changes, whether by uniting with the Salts of the Air and Ocean, or otherwiſe, as prove not unfrequently deſtructive or noxious to the Creatures that inhabit thoſe Elements. For this putrefied Matter appears to be in itſelf a Kind of Poiſon, infecting the Air wherein it ſpreads; ſo as to occaſion peſtilential Diſeaſes near the Places where great Battles have been fought, when the unburied Carcaſes of the Slain thus reſolve and go off into the Atmoſphere. Many other Inſtances we have of the poiſonous Nature of putrefied animal Subſtances, in rotten Eggs, mortified Fleſh, and the like: whence this ſeems to be another particular Species of *Fermentation.* *Extended.*

52. It has been diſputed, whether there be a real Fermentation in the preſent Caſe. But ſuppoſing this not to be a Diſpute about Words, it ſhould ſeem that there is a proper Species of Fermentation, peculiar to animal Subjects, as there is one peculiar to Vegetables. Till this Point be ſettled, we ſhould not lay down vegetable Fermentation, as the Teſt and Standard of Fermentation in general, and ſo judge of all other Kinds according as they approach to, or recede from, this Standard. For want of diſtinguiſhing in this Caſe, all true Fermentation ſeems denied to the Blood and Juices, circulating in a living animal Body, as well as to the Sap of Vegetables. But were the Enquiry into Fermentation proſecuted in its full Latitude, and not arbitrarily *Fermentation determined.*

arbitrarily confined to any ſingle Species, perhaps many natural and artificial Operations would prove to be actual Fermentations. To ſay that there is no Fermentation in the Blood, becauſe it affords no inflammable Spirit upon Diſtillation, is in effect the ſame as to ſay that Blood is not Wine. Whereas the Queſtion is not whether there be a *vegetable Fermentation* in the Blood, but whether there be not an *animal one*; the Criterion whereof is the Production of a volatile urinous Salt, as the Production of an inflammable Spirit is the Criterion of vinous Fermentation.

Chemiſtry of Nature in Bodies. 53. And here is a Door opened for enquiring into the Chemiſtry of Nature, as it is exerciſed in the Bodies of Men; ſo as to diſcover the natural Means whereby vegetable Subſtances taken in at the Mouth, by the Way of Aliment, are prevented from running into vinous or acetous Fermentation; but are, on the contrary, changed into a balſamic, unctuous, and milky Liquor, or Chyle, that turns red in the Arteries, recruits the Blood, and nouriſhes the Body. For all this ſeems to be the Effect of a peculiar *animal Fermentation*, the Laws and Proceſs of which are little conſidered. And in this View, the ſeveral Juices of the Body, as the Saliva, Bile, Pancreatic Juice, *&c.* may be regarded as animal *Menſtruums*, acted upon, and made to act in the Body, by determinate Motions, for determinate Ends.

III.

EXPERIMENT VIII.

That there may be a Kind of Fermentation in mineral and metallic Bodies.

Mineral Fermentation. 54. We took an Ounce of Lead and as much Biſmuth, and melted them together in an Iron

Ladle; then heating two Ounces of Quickſilver in another Ladle, we mixed all the three metallic Matters together as an Amalgam; which, when cold, appeared perfectly uniform or homogeneous, and totally paſſed thro' the Pores of Leather in a running Form. But this Mixture being ſuffered to cool, and ſtand quiet for ſome Hours, a groſs Matter ſeparated from it by Degrees, and floated upon the reſt; which was left ſo thin and fluid, as to paſs through Leather, leaving the groſs metallic Matter behind.

The Experiment extended.

55. Hence it ſhould ſeem that even metallic Matters may have their peculiar Fermentations, as well as vegetable and animal Subjects. For when the preſent Experiment comes to be carefully conſidered, it appears to have all the Requiſites of Fermentation. For here is, (1.) a fluid Form, (2.) an uniform Matter, (3.) an inteſtine Motion, and (4.) an actual Separation of a groſſer Matter, leaving a thinner behind. All which Particulars we have found to hold in the ſeveral Species of Fermentation above examined.

56. There are many more Inſtances of an apparent Fermentation in mineral Bodies, one or two whereof it may be proper to mention. Thus, if an aqueous Solution of the common green Vitriol be expoſed to the Air in the Summer-time, and kept continually ſupplied with freſh Water as the former exhales, the groſſer metallic Part of the Vitriol will ſubſide, and the reſt gradually ſhoot upwards all round the Veſſel, in Form of an unctuous, cruſty Matter; till the whole Body of the Vitriol is thus ſucceſſively ſo altered that the Part ſhot into the cruſty, unctuous Form, will neither become Vitriol again, nor corrode any freſh Metal; and in all other Reſpects it appears a different Thing from Vitriol. And

hence ſeem to proceed the Complaints of the Makers of Vitriol, that in rainy, windy, and cloudy Weather, their Vitriol-Stones, which lie open to the Air, will not ſometimes yield a ſolid cryſtalline Vitriol, but only an unctuous Matter. This may therefore appear to be a Fermentation in all its Forms, as being attended with a ſpontaneous inteſtine Motion, a ſpontaneous Separation of conſtituent Parts, and a remarkable Alteration of the Subject.

57. It alſo makes to the preſent Purpoſe that ſolid and hard Pyrites, or Vitriol-Stones, being expoſed to the Air and moiſtened with Water, will, like a vegetable Subject *a*), grow hot, fume, and even take Fire, as was obſerved in our fourth Lecture, and afterwards afford Vitriol; a Thing very different from the Stones themſelves *b*). So that, upon the whole, we may conclude, that in a proper Senſe, there is an actual *Fermentation* exerciſed, not only in the vegetable and animal, but alſo in the mineral Kingdom.

V.

AXIOMS *and* CANONS.

1. All the Inſtances being duly conſidered, and a large View of Things taken in, we may define *Fermentation*, in general, a ſenſible internal Motion of the conſtituent Particles of a moiſt, fluid, mixed, or compound Body; by the Continuance of which Motion, thoſe Particles are gradually removed from their former Situations, or Combinations; and again, after ſome viſible Separation is made, joined together in a different Order and Arrangement. And thus the whole

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a) See above, *Exp.* VI.
b) See *Lect.* IV. *Exp.* V.

whole Proceſs of Fermentation conſiſts of two different Operations, *viz.* an *Analytical* one, whereby the Particles are reſolved, and a *Synthetical* one, whereby they are new ranged: So that whenever theſe two different Effects are found to be produced, in direct Sequence, with the Circumſtances above deſcribed, we need not ſcruple to call the Operation by the Name of *Fermentation*, whether it happen in the Blood, or other animal, vegetable, or mineral Subſtances *a*).

2. That all ſeparable, mixed, or compound Bodies may be the Subjects of this general Operation; but that the eaſier they are ſeparable by Means of Water, Air, and Heat, the more readily they ferment *b*). Thus the ſweet or ſaccharine Part of Malt, more readily diſſolving in warm Water, ferments eaſier than unmalted Corn, which is more clammy and will not diſſolve ſo ſoon. And hence the Fleſh of animal Bodies putrifies ſooner than the Bones. And this appears to hold in all Inſtances *c*).

3. That this general Fermentation is diviſible into many diſtinct Species, particularly into *vegetable*, *animal*, and *mineral d*); the vegetable Kind again into *vinous*, *acetous*, and *putrefactive*; the vinous again into mucilaginous, mouldy, and putrefactive; and ſo of the acetous, *&c.* Whence we may deduce a *Canon* for adjuſting all the different Species of Fermentation; which being once fixed might put an End to infinite hypothetical Diſputes upon this Subject, and lead to farther Diſcoveries both in Nature and Art.

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a) See the whole Lecture, *paſſim.*
b) See *Exp.* I. VI.
c) See *Exp.* I. VI. VII.
d) See the whole Lecture, *paſſim,*

4. That it is in the Power of Man to prevent, ſtop, and regulate theſe natural Operations at any aſſigned Point of Time. Indeed it is thus we come by our Wines and Vinegars; It is thus that Men diſcovered the Art of Embalming; It is thus we preſerve many vegetable, and animal Juices, in their natural or unfermented State; It is thus we preſerve Yeaſt, and Wine-Lees, Subjects extremely apt to putrefy; It is thus we can at any Time ſtop the Courſe of vinous Fermentation, and produce a ſweet, or half fermented Wine; It is thus we cure the Frettings, or other Diſeaſes of Wines; and thus we ſtop Mortifications in the Body, and Caries in the Bones. And moſt of the Artifices employed for theſe Purpoſes, depend upon a Knowledge and Regulation of the phyſical Cauſes and Inſtruments that produce the Change; which Cauſes and Inſtruments, as we above diſcovered, are chiefly, Heat, Moiſture, and the external Air *a)*.

5. That a ſaccharine Matter is the Baſis of Wines, Vinegars, and inflammable Spirits *b)*.

6. That a great variety of ſound, perfect, and wholeſome Wines may be made, in Countries that do not naturally afford Grapes, by a prudent Uſe of Sugar, or Raiſins and Water *c)*.

7. That the Matters called Ferments are of Uſe in beginning, regulating, and determining the Species of Fermentation *c)*. Thus freſh Yeaſt determines the Fermentation of Wheat-Flour to make our common Bread, which would prove of another Kind, if the Flowers or Lees of Vinegar were uſed. And thus ſpecific or de-

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a) See the whole Lecture, *paſſim.*
b) See *Exp.* I. §. 15. &c.
c) See *Exp.* I.

terminate Ferments have their correſpondent Effects. If Sugar, Honey, Manna, Treacle, or new Wine be added to Vinegar, themſelves are ſoon changed into Vinegar, without ſtopping to make Wine; becauſe the acetous Ferment, or Vinegar, over-rules them. And ſo Vinegar is ſooneſt made in a Caſk that has before contained the ſame Liquor. And if the beſt Wine were put into a Caſk that had held putrefied Vinegar, the Wine would not now make Vinegar, but immediately run into Corruption. So great and ſo deciſive a Power have ſpecific Ferments; the Uſe whereof is therefore evident, and may afford conſiderable *Rules* in Chemiſtry, practical Philoſophy, and Arts.

8. That the Degrees of Fermentation differ with the Degrees of Heat employed *a).* Thus we ſaw vinous Fermentation required a leſs Degree of Heat than the acetous; the acetous a leſs than the putrefactive; which latter may even conſiſt with a Degree of Ignition *b).*

9. That a particular Kind of Fermentation may be carried on in the living Bodies of Animals and Vegetables, which are largely ſupplied with the requiſite Inſtruments of Fermentation, *viz.* Water, Air, and Heat: And in Fact both Vegetables and Animals appear to have an inteſtine Motion in all their circulating Fluids, which continually depoſite a groſſer Matter in the Canals and Parts they move through. Whence, by our Definition of Fermentation *c)*, this natural Act may be accounted a Species of Fermentation, producing a Change in the nutrimental Matter of Vegetables and Animals, and converting it into their own Subſtance.

a) See *Exp.* I, II, III, IV, V, VI.
b) See *Exp.* VI.
c) See *Ax.* I.

10. That when Vegetables or Animals die, there ſoon begins a different Kind of Fermentation in all their Parts; tending now not to the Repair, but to the entire Deſtruction, of their organical Veſſels, the confuſed Mixture of their ſolid Parts and Juices, and a Volatilization of their whole Subſtance *a)*.

11 That dry or ſolid Bodies cannot, in that State, undergo a proper Fermentation: for tho' they may in that State be ſeparated into minute Particles, yet they cannot range themſelves together in any new Order, nor depoſite a groſſer Part, without being agitated by ſome Fluid, or ſuſpended therein for ſome Time. And hence, in over-heated Mines, the Ore is thus *analytically* deſtroyed, and cannot range itſelf into a metalline, or any other regular Order again, for want of the requiſite Moiſture or Fluidity; whence the Matter appears like a Heap of rotten Earth, or what the Miners call *Dead Metal b)*; of which we have a remarkable Inſtance in the over-heated or fired Mixture of Sulphur and Iron-Filings *c)*.

12. That the terreſtrial, marine, and atmoſpherical Regions have each their proper *Fermentation*, different in Kind, and ſubdiviſible into particular Species, whereby the Changes of all Bodies one into another are naturally performed *d)*; And that in Imitation hereof, by a thorough Knowledge of the natural Agents that produce theſe grand Effects, Art likewiſe may produce extraordinary Changes in Bodies *e)*.

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a) See *Exp.* V. VI.

b) See *Exp.* VIII.

c) See *Lect.* XIX *Exp.* III.

d) See the preceding *Lectures* upon the *Elements*. See alſo that upon *Menſtruums*, and the ſeveral Experiments in the preſent *Lecture*.

e) See *Lect.* I. *paſſim*.

LECTURE VIII.

CONTAINING

Analytical Chemiſtry; *or, the Art of Analyſing Vegetable, Animal, and Mineral Subſtances, and reſolving them into different Parts or Principles.*

I.

1. THE whole of Chemiſtry may be comprehended under the Art of reſolving Bodies into their Principles, and of compoſing new Compounds from thoſe Principles, by Means of the common Elements, Fire, Air, Water, Earth, and particular *Menſtruums.* We ſhall accordingly in our preſent Lecture, endeavour to enquire into the Buſineſs of chemical Reſolution, in the vegetable, animal, and mineral Kingdoms, with a View to diſcover what uſeful *Principles* may be thence obtained; intending, in our next Lecture, to conſider the correlative Buſineſs of Compoſition: ſo that the two together may contain a ſummary Account of the Nature, Office, and Uſe, both of analytical and ſynthetical Chemiſtry; of which the one takes Bodies to Pieces, or reduces them to their component Matters, and the other, by putting theſe Matters or different Pieces together again, in various Manners, forms a large Set of new Productions, that would be unknown to Nature without the Interpoſition of Art. And ſuch Productions, for Inſtance, are, *Brandy*, *Soap*, *Glaſs*, &c. *Subject.*

2. But before we enter upon the Enquiry itſelf, it is neceſſary we ſhould diſtinctly explain what *Principles what.*

what we mean by the Word *Principle*, about which many Diſputes have been raiſed We muſt therefore obſerve, that the more intelligent among the modern Chemiſts do not underſtand by *Principles* thoſe original Particles of Matter, of which all Bodies are by the mathematical and mechanical Philoſophers ſuppoſed to conſiſt. Thoſe Particles remain undiſcernible to the Senſe, tho' aſſiſted with the moſt finiſhed Inſtruments; nor have their Figures and original Differences been determined by a juſt Induction. Leaving, therefore, to other Philoſophers the ſublimer Diſquiſition of primary Corpuſcles, or Atoms, of which many Bodies and Worlds have been formed in the Fancy, genuine Chemiſtry contents itſelf with groſſer Principles, which are evident to the Senſe, and known to produce Effects in the Way of corporeal Inſtruments. And theſe groſſer Principles are every Way ſufficient to anſwer the Purpoſes of philoſophical Chemiſtry, which conſiſts wholly in Experiment, and the Explanation of Facts and ſenſible Operations. Where, by the Way, it may be obſerved, that Chemiſtry is an Art extremely well ſuited to the Nature of Man, as it requires nothing more than the Uſe of ſuch Faculties as he evidently finds himſelf poſſeſſed of. But when once we leave the Oracles of Senſe, and introduce metaphyſical Speculations and Notions into Chemiſtry, it then becomes a corrupt Fountain of Hypotheſis and Illuſion. To rectify Chemiſtry, therefore, the Rule is to keep cloſe to the Information of our Senſes, the Laws of Induction, and the Uſe of material and ſenſible *Principles*.

3. Theſe ſenſible Principles, ſo far as we know them, are ſignificantly expreſſed by the common Words, *Water*, *Earth*, *Salt*, *Sulphur*, and *Mercury*: to which might be added the Air, if a Way

were known to fix it, ſo as to render it more ſenſible, tangible, and corporeal *.

4. By *Water* we underſtand a ſenſible, tranſparent Liquor, without Taſte or Odour; that freezes with a certain Degree of Cold, and liquifies from that State with a certain Degree of Heat; that extinguiſhes Fire, *&c.* By the Chemiſts this is otherwiſe called *Phlegm.* *Water.*

5. By *Earth* we underſtand an inſipid, dry, powdery Subſtance, that will neither diſſolve in Water, nor burn away in a ſtrong Fire; but, with the Addition of fixed Salt, melts into Glaſs. *Earth.*

6. By *Salt* we underſtand any ſenſible Body that readily diſſolves in Water, taſtes ſharp or pungent upon the Tongue, and has a great Diſpoſition to unite with Earth, ſo as to appear in a ſolid Form; as in common Salt, Alum, *&c.* *Salt.*

7. By *Sulphur* we mean any Matter that will readily burn and diſappear in the Fire, and that will not eaſily, or of itſelf, mix with Water. *Sulphur.*

8. And laſtly, by *Mercury* we underſtand a ſenſible Body that has the Fluidity, Gravity, and Appearance of common Quickſilver. *Mercury.*

9. We do not lay down theſe as adequate Definitions, but only as ſenſible Marks whereby the Things meant may be readily known and diſtinguiſhed for ordinary Uſe. Juſt Definitions can be drawn only from a full and perfect Diſcovery of the Nature and Properties of Bodies, which we are far from knowing; nor do we uſually meet with any of theſe Principles in a pure and perfect State, unmixed with other Bodies. When they appear to the Senſes to be thus far purified, they are the Principles we mean, or what we

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* See *Lect.* III. *Exp.* X.

emphatically call the *Chemical Principles*; tho' they may be every one of them deſtructible, as to that Form: but then they ceaſe to be chemical Principles.

10. And thus we have endeavoured to ſettle the chemical Meaning of the Word *Principles*, and to lay down Marks or Criterions for diſcovering and diſtinguiſhing them, when we meet with them hereafter in the following Experiments.

11. Theſe Experiments we ſhall endeavour to make as general as we can, and give an Example in each of the three Kingdoms, as they are called, *viz.* the Vegetable, Animal, and Mineral.

EXPERIMENT I.

That Vegetables are reſoluble, by Fire, into four of the chemical Principles, viz. Water, Oil, Salt, *and* Earth.

Wormwood analyſed.

12. We took two Pounds of common Wormwood cut ſmall, which we put into a Glaſs Retort in a Sand-Heat, and diſtilling with Degrees of Fire, and a frequent Change of Receivers, we obtained (1.) an aqueous Liquor, and (2.) an Oil. Then taking out the Remainder, and burning, or calcining it, in the open Air, it turned to a grey Kind of Aſhes; which being boiled in fair Water communicated thereto (3.) a Salt. This Salt we obtained in a dry Form, by letting the Solution ſtand at Reſt for ſome Time, then decanting the clear Liquor, and exhaling the ſuperfluous Water. And (4.) we found an earthy Subſtance remaining at the Bottom of the Water wherein the Aſhes were boiled.

The Experiment made general.

13. This Experiment being well attended to is very inſtructive, and ſhews that the *chemical Princi-*

Principles above-mentioned are not imaginary or fictitious Things; but Things palpable, and evident to the Senſes. For here we have a Water, an Oil, a Salt, and an Earth, all afforded us by a vegetable Subject. And the Experiment may be made general without much Variation: for all the vegetable Subjects hitherto examined, in this Manner, reſolve themſelves into the ſame general Principles, which differ only (1.) in Reſpect of the Kind of Salt; that being in ſome more volatile, in others more fixed; in ſome acid, in others alkaline; and (2.) in the Nature or particular Properties of the Oil; which in ſome Plants is thinner and more fluid, in others more groſs and viſcous; *&c.* But all the Principles thus obtained agree to the general *Definitions* above laid down *. So that there appears to be no Vegetable in Nature, but what is thus reſoluble into Water, Oil, Salt, and Earth.

The Water purified.

14. To obtain theſe Principles pure, we muſt (1.) ſeparate all the Oil that may chance to remain ſuſpended in the *Water*. This is effected, in a conſiderable Degree, by the Filtre; which being kept continually filling up, ſo as that the lighter Oil may not come in Contact with the Paper, the aqueous Part is thus tranſmitted tolerably free from Oil. (2.) But ſtill there may remain ſome ſmall Proportion of oily and ſaline Matter therein? If the ſaline Matter be acid, the way to deſtroy it is, to mix a little Chalk, or any pure and fixed alkaline Salt, with the Liquor. By this means alſo more of the Oil will be ſet free; ſo that being now filtred again, and gently diſtilled with a ſoft Heat, the aqueous Part will riſe much purer, and paſs for Water in the Judgment of the Senſes. (3.) If the Plant

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* Sect. 4—8.

was alkaline, and an alkaline Salt abound in the aqueous Liquor, let it be made neutral with one that is acid; and thus again the Water may be ſeparated pure, by means of the Filtre and Rediſtillation. And this is the Method of manifeſting to the Senſes, that the chemical Principle *Water* is naturally lodged in, and may be ſeparated from all vegetable Subſtances *.

The Oil purified.

15. In order to procure the *Sulphur*, or oily Principle, pure, the unctuous Matter, obtained by this general Proceſs, may be waſhed from its adhering Salts and groſſer Earth in warm Water, barely by ſhaking them in a Glaſs together, and then ſeparating the Oil from the Water by means of the common ſeparating Glaſs; where, if the Oil be ſpecifically heavier than Water, it ſinks to the Bottom, and may be ſuffer'd to run out firſt; if ſpecifically lighter, it floats a-top, and may by the Finger applied to the Bottom of the Glaſs, or ſome other Contrivance, be kept behind, when all the Water and feculent Parts are run from it.

The Salt purified.

16. To obtain the ſaline Principle pure; (1.) if it be of the volatile urinous Kind, the Matter may be diſſolved in Water, and made to paſs the Filtre; then ſet in a gentle Heat to ſublime: for it will thus riſe and leave the Water behind, as being much more volatile than that. (2.) If it be required ſtill purer, the beſt Method hitherto known is, to ſublime it from finely pulverized Chalk; then to ſaturate it with a clean Spirit of Sea-Salt, ſo as to convert it into a true Sal-Ammoniac; which being mixed with Salt of Tartar, and again ſet to ſublime, the volatile Salt will riſe highly purified, ſo as long to retain its Whiteneſs. (3.) But if the ſaline

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* See *Lect.* V. *Exp.* I.

Matter obtained be of the fixed Kind, the Method of purifying it is, to diſſolve it in fair cold Water; ſuffer the Solution to ſubſide; then decant the clear Liquor, and evaporate it in a clean Iron Pan or Glaſs Veſſel, conſtantly ſtirring it, till it becomes dry and white: (4.) Or to purify it ſtill farther and render it perfectly white, let it be put into a clean Crucible, and expoſed for a while amidſt the Flame of burning Charcoal, but without Melting it.

The Earth purified.

17. Laſtly, to obtain the earthy Principle in its Purity, let it be thoroughly calcined, boiled in ſeveral Waters, in order to get out all its Salt; then dry it over a clear Fire, or in the Sun. And if theſe ſeveral Operations be performed in Perfection, we then obtain what we properly mean by the *chemical Principles of Vegetables.*

18. And tho' it be not always neceſſary for the Purpoſes of Chemiſtry, or the common Calls of Life, to bring theſe Principles to the Degree of Purity here mention'd, yet there are many Caſes that abſolutely require them to be ſo purified; otherwiſe the Operations in which they are employed may eaſily miſcarry: and this we deſire may be noted as one conſiderable Reaſon of the Failure of particular Experiments and Operations, both in Chemiſtry itſelf, and in many of the chemical Arts; particularly the Art of Glaſs, Diſtillation, &c.

Uſes of the Experiment.

19. The Uſes of this leading Experiment are numerous; we ſhall touch upon a few of them. And firſt, we may learn from it that theſe chemical Principles are found in different Quantities in different Vegetables, or in the ſame at different Seaſons or Times of Growth. Thus, for inſtance, Olives, Almonds, Mace, &c. contain ſuch an Over-Proportion of Oil, to the other

Principles, that it may be copiouſly got from them barely by Preſſure. The Vine in the Spring affords a larger Proportion of fixed alkaline Salt than at any other Seaſon; and the ſame holds of the Wood uſually burnt for Pot-aſh. And thus we find that the aqueous and ſaline Principles preſide in Vegetables in the Spring, but the oily in the Summer and Autumn; that all young Plants abound more with Water, than ſuch as are full grown; and that Oil is moſt plentifully contained in the oldeſt Trees, and thoſe of the colder Climates. Whence we are directed to the proper Times, Seaſons, and Places for felling the Timber deſigned for Pitch, Pot-aſh, Fewel, and Charcoal.

20. By applying this Experiment to different Vegetables it has been found, that Vegetables are naturally diſtinguiſhable into two grand Tribes, *viz.* the Acid and the Alkaline; the firſt affording a volatile Acid, and the other a volatile Alkali, upon dry Diſtillation. Thus Guaiacum, Cedar, Box, Cinamon, Cloves, Sorrel, Mint, Baulm, *&c.* afford an Acid; but Garlick, Leeks, Onions, Horſe-radiſh, Scurvy-graſs, Muſtard, *&c.* afford an Alkali; which, when rectified, is hardly diſtinguiſhable from that of animal Subſtances, ſo as nearly to reſemble the Spirit and Salt of Hartſhorn *a*).

21. This Experiment alſo ſhews us the Methods of making or procuring Tar, Charcoal, fixed Salt, and elementary Earth, from Vegetables; four capital Things in Arts and Trades. Tar is the ſcorched Oil of unctuous Wood, forced out by Fire, as the groſs Oil is in the *preſent Experiment b*). Charcoal is Wood burnt cloſe

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a) See *Lect.* VII. *Exp.* VI.

b See alſo *Lect.* II. *Exp.* III.

to Blackneſs a); Soap, a Mixture of fixed Salt and Oil; Glaſs, a mixture of Earth and fixed Salt; and elementary Earth makes all the Teſts and Coppels for refining of Gold and Silver.

22. Again, the preſent Experiment ſhews us the Nature of vegetable Fumes, by which, in the Way of animal Curation, Fiſh and Fleſh are long preſerved, free from Putrefaction or Corruption. For where-ever green Wood, or any acid vegetable Matter is burnt, the acid Particles riſe with the Smoke, and in this Form penetrate and lodge in animal Subſtances expoſed thereto; ſo that this Smoke acts upon them in the ſame Manner as the Fume of Spirit of Sea-Salt or Nitre would do. And whether it be not a nitrous Acid which thus tinges the Hams, Herrings, *&c.* red in drying, we recommend to farther Examination.

23. Our Experiment alſo confirms what was before obſerved b), that the Force of Fire is not ſufficient to reduce a vegetable Subſtance to Aſhes without the Help of the Air, and that ſo long as the fixed Oil, which cauſes the Blackneſs, remains in a vegetable Coal, it will afford no fixed Salt by Decoction in Water c). Whence for making Pot-aſh, and all the fixed Salts, to Advantage, we have this Rule, thoroughly to calcine the Subject, ſo as to leave no fixed Oil behind.

24. And hence we are alſo inſtructed in the phyſical Nature of a vegetable Coal, and ſee how it may have ſuch conſiderable Effects upon Metals, in the Way of a *Flux*; ſince we find it contains a fixed Oil, firmly united to the Matter of a fixed Alkali; whence, to uſe this Coal as a Flux, is the ſame Thing as to uſe a fixed Salt

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a) See alſo *Lect.* II. III.

b) *Lect.* II. *Exp.* IV.

c) See *Lect.* II. *Exp,* IV.

intimately united with a fixed Oil, which operates powerfully upon Ores, as we have formerly ſhewn *. And ſo much for the *Analyſis* of Vegetables.

II.

EXPERIMENT II.

That animal Matters are reſoluble, by Fire, into the four chemical Principles, Water, Oil, Salt, *and* Earth.

Bone analyſed. 25. We took four Pounds of animal Bones, that had been well boiled to get out their Marrow or Fat, and then thoroughly dried again; and breaking them into ſmall Lumps, we put them, dry as they were, into an earthen Retort, luted on a Glaſs Receiver, and diſtilled, with Degrees of Heat, in a naked Fire. There firſt came over in Drops an aqueous limpid Liquor, which we reſerved apart, by changing the Receiver. Then increaſing the Fire there came over white Fumes, a volatile Salt, and a Quantity of Oil. The Veſſels being ſuffered to cool, we found the Bones turned black in the Retort; but being calcined in a naked Fire, with the Admiſſion of the free Air, they turned to white Aſhes. Then boiling theſe white Aſhes in Water, we found by Evaporation that they communicated no fixed alkaline Salt thereto.

The Experiment extended. 26. This Experiment is general, or ſucceeds, with little Variation, in all other animal Subjects, whether they be Fleſh, Blood, Serum, Fiſh, Birds, Snakes, the Whites of Eggs, Horn, Hair, Hoofs, Silk, or the like; the principal Difference being only, that theſe Subſtances reſpectively contain more or leſs Earth, Water, Salt, and Oil. Thus Blood being diſtilled in its natural State, or as it is drawn from the Vein of a healthy Perſon, will yield about ſeven-eighths of its Quantity in Water. And if any animal Subject be not well purged of its Oil, by boiling in common Water, before it is committed to Diſtillation, it thence affords a greater Quantity of a burnt empyreumatical Oil, that ſtrongly taints and impregnates the volatile Salt and Water, with a nauſeous Scent and Taſte; which are hard to get rid of, even by repeated Rectifications.

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* See *Lect.* I. *Exp.* III. See alſo hereafter the Lectures upon *Mineralogy* and *Metallurgy.*

Its Uſes.

27. The Principles ſeparated by the preſent Experiment appear to be, in general, the ſame with thoſe before gained from a vegetable Subject. They may be ſeparately purified and made elementary, after the ſame Methods as we there laid down. And thus, by comparing the Productions of both Proceſſes together, we ſhall find that we have a Water, an Oil, a Salt, and an Earth in both Caſes.

28. The two Waters ſeem ſcarce to differ, when reduced to the ſame Degree of Purity; no more do the Oils and the Earths; but all the Salt in the preſent Caſe is volatile; the Aſhes containing no fixed Salt at all: whence this appears to be the principal chemical Difference betwixt vegetable and animal Subjects, that the vegetable Kind yield a fixed Salt by Calcination, and the animal Kind, one that is volatile by Diſtillation. But this holds only of the acid Species of Vegetables; for the alkaline Species yields little or no fixed Salt upon Calcination. So that betwixt the alkaline Tribe of Vegetables, and the whole animal Kingdom, there ſeems to be little Difference; either in this, or any other chemical Reſpect *. But tho' ſome Difference

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* See *Lect.* VII. *Exp.* VI.

ſhould be found betwixt the animal and vegetable Oils, as there is thought to be in the Making of Soap, and ſome other Inſtances; yet the Principles of animal and vegetable Subjects may be juſtly reputed the ſame, as both equally agree to our general Definitions of Water, Oil, Salt and Earth *a*) But when the ſeveral Principles of Vegetables and Animals are reduced to the ſame Degrees of Purity and Fineneſs, there ſeems, ſo far as our Trials have gone, to be no ſenſible Difference between them. Thus the pure elementary Earth of Vegetables ſerves for the making of Teſts and other Purpoſes, as well as the elementary Earth of Animals; ſolid Soap is made of vegetable Oils, as well as of animal Fats; and the volatile Salt of alkaline Vegetables, or even of acid Vegetables when putrified, is not to be diſtinguiſhed from the volatile Salt of Animals, when both are thoroughly purged and purified.

The animal Principles how purified.

29. But the Labour and Difficulty required, to bring theſe Principles to a high Degree of Purity, has proved a chief Cauſe of their being thought different; for we ſee that the Oil tenaciouſly adheres to the volatile animal Salt, and thus adds ſome Qualities that do not properly belong to that Salt. But if a volatile animal, and a volatile vegetable Salt, be each ſeparately converted into Sal-Ammoniac, by Means of Spirit of Sea-Salt, no ſenſible Difference can be found betwixt them. And thus, if a vegetable Oil and an animal Oil were equally purified, ſubtilized, and freed from all the Matters that do not eſſentially belong to them, they would not ſenſibly differ. At leaſt, this ſeems confirmed by ſeveral Experiments *b*).

a) See above, §. 4—8.

b See Dr. *Cox*'s Papers in the *Philoſophical Tranſactions.*

30. And

33. And hence may ſome Advantages be derived to Arts and Trades, by making the Subjects of one Kingdom ſerve for thoſe of the other, where the one is cheaper than the other. Thus, as we before obſerved *, a volatile Spirit and Salt, like thoſe of Hartſhorn, may be drawn from the alkaline Species of Vegetables, and all putrefied Plants; at leaſt from Bones, purged of their Fat by boiling in Water. *Farther Uſes.*

31. The preſent Experiment has many other Uſes and among the reſt remarkably ſhews how a perfectly dry, inſipid, ſcentleſs, and ſolid Body may yield a great Variety of Taſtes and Odours, barely by being applied to the Fire. For the impure Water, the volatile Spirit, the Salt and the Oils, have each a particular Taſte and Odour. And tho' the Subject itſelf were fixed, we ſee it nevertheleſs affords ſeveral volatile Matters. And as this fixed Subſtance was originally compoſed of a fluid Matter, we are hence taught that the animal Solids and Fluids have the ſame common Nature; their Difference conſiſting only in a greater or leſs Proportion of Water and Earth. For Blood, upon the like Analyſis, affords more Water and leſs Earth than Bone.

32. This Experiment likewiſe ſhews us that a Bone may be entirely diveſted of its Water, Salt, and Oil, without loſing its priſtine Figure and Dimenſions. For after thoſe Principles are ſeparated from it, the elementary Earth, tho' abſolutely dry and friable, ſtill hangs together in the natural Form and Figure of the Bone; which thus remains exhauſted of all that Matter, which the Fire was able to carry off, without affecting the elementary Earth itſelf.

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* See *Lect.* VI. *Exp.* VI.

Whence we evidently ſee that the Uſe of this elementary Earth, in vegetable and animal Bodies, is to afford a Lodgment, a Support, or Skeleton to the other Principles, which are much more diſſipable and deſtructible than itſelf.

33. And as our Experiment ſucceeds alike in all animal Matters, and even in the Jelly obtained from a Bone by long Boiling, till the elementary Earth is elixated, or drained of the other Principles; we hence learn that the Matter of theſe other Principles proceeds only from the Juices of the Body, where, as well as in the Jelly, they appear in an almoſt inſipid and inodorous State, yet are capable, by Diſtillation, of affording Subſtances ſo highly ſapid and odorous, as we find the volatile Salt and Oil to be. Whence this Concluſion naturally follows, that theſe Principles did not exiſt in a volatile State in the Body, as requiring even a greater Degree of Heat, than that of boiling Water, to ſeparate them.

34. We may farther obſerve that the preſent Experiment affords us the moſt volatile Subſtance hitherto known; for well-purified animal Salt is more volatile than Spirit of Wine, and riſes in Diſtillation before it, Hence this Salt readily evaporates in the open Air, and being laid upon the Palm of the Hand goes off inſenſibly, without any Effect; tho' if it were preſſed cloſe to the Skin, by a ſticking Plaiſter, it would prove corroſive; and in this Manner it is ſometimes uſed, for making Iſſues in Children, inſtead of the ſtronger Cauſticks.

III.

EXPERIMENT III.

That certain mineral or metallic Bodies may contain four of the chemical Principles, viz. Sulphur, Salt, Earth, *and* Mercury.

35. We took two Ounces of native Cinnabar reduced to fine Powder, and mixing it with ſix Ounces of Quick-lime, we put the whole into an eathern Retort, and diſtilling into a Baſon of Water, we found a conſiderable Quantity of running Mercury at the Bottom thereof *. The Matter remaining behind in the Retort being boiled in a *Lixivium* of Pot-aſh, and the Solution precipitated with Allum, lets fall a fine Kind of Brimſtone called *Lac Sulphuris*, which will ſublime into true Flowers of Brimſtone, that may be melted, and run into a Roll. This Brimſtone being burnt, in the common Method, under a Glaſs Bell, reſolves into an acid Liquor, leaving an uninflammable, ſcurfy, terreſtrial Matter behind; which being treated as an Ore, ſometimes affords a ſmall Proportion of Metal, either Iron or Copper. *Cinnabar analyſed.*

36. We have here an inſtructive Experiment, which being fully explained might lead to conſiderable Diſcoveries. It ſhews that a true running Mercury may lie concealed in metallic Ores, or ſtony Earths; for native Cinnabar is but an Ore of Mercury, conſiſting, as we ſee, of two different Matters, Sulphur and Quickſilver, which

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* We endeavoured to ſeparate the Sulphur from the Cinnabar, by boiling ſome pulverized Cinnabar in a ſtrong *Lixivium* of Pot-aſh and Quick-lime, expecting the Mercury ſhould fall to the Bottom in a running Form; but had no Succeſs at the End of two or three Hours.

ſilver, which are ſeparable by Diſtillation with Quick-lime or Iron Filings; and ſometimes by long Boiling in a ſtrong alkaline *Lixivium.*

The Experiment whether extendible

37. It were highly proper, if poſſible, to render the preſent Experiment general; and, if the Nature of the Thing would admit thereof, apply it to extract a running Mercury from Metals, as we have here done from a native Ore or mineral Subſtance. For the more intelligent Chemiſts agree, that the true Analyſis of metalline Minerals depends upon what is called their *Mercurification*; that is, the obtaining Mercury from them. And for this Purpoſe there are three Methods propoſed. The firſt is by Means of a certain Mercury, ſo prepared as to have a diſſolving Power, and to take up the Mercuries of Metals, in the ſame Manner as Water diſſolves Salt from Aſhes. The ſecond is by Means of certain regenerating Salts, particularly *Sal-Ammoniac*, which ſhall detain the more earthy Parts of Metals, and leave their Mercuries ſeparable from them by Sublimation or otherwiſe. And the third Method is by Means of a large *Lens*, or double Convex Glaſs; in the Focus whereof, if any Metal be applied, its mercurial Part is ſaid to ſeparate and go off in Fume, which when collected and condenſed appears to be running Mercury.

38. The firſt Method would be eaſy, if the proper Mercury for the Purpoſe could be readily procured. The ſecond is extremely laborious, and requires much Patience, and Reiteration. But the third ſeems eaſy enough, and practicable to Advantage, when a Glaſs of three or four Foot in Diameter is at hand, the Sky ſerene, and the Sun ſhines ſtrong *.

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* See M. *Homberg*'s Experiments, with the Duke of *Orleans*'s Lens, in the *French Memoirs.*

39. Let us not be miſapprehended as if we were here launching out beyond the Confines of genuine Chemiſtry, whoſe Office it is to keep cloſe to the Senſes, without indulging any Degree of Speculation and Hypotheſis: we only mean to give an Occaſion for proper Trials to be made, which alone can determine whether running Mercuries are obtainable from Metals, or whether a fixed Metal may not be obtained from running Mercury. Indeed we ſhould be wanting to the Art we are endeavouring to improve, if we did not, at a time when almoſt every Chemiſt in *England* is preparing the *Mercurius præcipitatus per ſe*, requeſt them to try whether a ſmall Portion of their fluid Mercury is not by the Operation fixed into a ſolid Grain of Metal; and if ſo, what Metal it is, and whether more of it be not procurable by grinding their Precipitate, expoſing it again to Digeſtion, and repeating this Operation for a Number of Times ſucceſſively, till it may happen that Part of it will bear the Cupel.

40. In the ſame View we recommend it, to thoſe who deſire the Improvement of Chemiſtry, that they would procure a double Convex-Glaſs, three or four Feet in Diameter, and try whether, when a Metal is expoſed to the Focus thereof, the metallic Matter which goes off in Fumes, being collected by a proper Veſſel dextrouſly applied and plunged in cold Water, may not be thus condenſed, and aſſume the running Form and other Properties of an actual Quickſilver. If theſe Experiments ſucceed, they may richly repay the Coſt, by uſeful Knowledge at leaſt.

41. But to proceed; we are farther to obſerve from the foregoing Experiment, that as common Brimſtone reſolves itſelf into an acid Liquor and an earthy Matter, we find that certain mineral

or metallic Subſtances will, by a proper Analyſis, afford the four chemical Principles above mentioned; *viz* running Mercury, Sulphur, Salt, and Earth. But it is not ſuppoſed to hold univerſally, that all mineral Subſtances ſhould afford a running Mercury upon their Analyſis; but only ſuch of them as are properly metallic.

Reſult of the Analyſis of Minerals.

42. So far as the Analyſis of Minerals has been carried, it ſhould ſeem that all Metals contain a running Mercury, fixed in them, as Water is fixed in dry animal or vegetable Subſtances *a*), and joined with a Sulphur, or an inflammable Part, and an Earth; beſides a little Salt in ſome of them *b*). The Foſſil Salts reſolve into a large Quantity of Acid, which is always united with ſome Sulphur, and a ſmall Proportion of Earth. Moſt Stones reſolve into a large Proportion of Earth, and a ſmall Quantity of aqueous and ſulphureous Vapour. And Earths reſolve into a mere terreſtrial Subſtance, a little aqueous Acid, and a ſmall Proportion of Sulphur.

43. Upon the whole therefore we may conclude, that the five Principles above laid down, *viz.* Water, Earth, Salt, Sulphur, and perhaps Mercury, are the true Chemical Principles of vegetable, animal and mineral Subſtances *c*).

AXIOMS *and* CANONS.

1. It appears from our preceding Enquiry, That genuine Chemiſtry conſiſts in a legitimate Uſe of the Senſes, keeping entirely to ſenſible

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a) See *Lect.* III. *ad finem.*

b) See M. *Homberg* upon the Chemical Principles, in the *French Memoirs.*

c) No notice is here taken of Air as a Chemical Principle, for the Reaſon before aſſigned. See above, § 3. See alſo *Lect.* III. *paſſim.*

Things, or the Law of Induction, for its Principles and Explanations *a*); but, if it once indulges hypothetical Notions, Fiction, Illuſion, and Darkneſs enſue, inſtead of ſure Rules, uſeful Diſcoveries, and Light to the Underſtanding.

2. That the common chemical Principles are juſtly ſaid to be Water, Earth, Salt, Sulphur, and Mercury; whereby many chemical Effects are explicable to common Senſe and Reaſon, ſo far as to afford Rules of working, to the Advantage of the Art and of ordinary Life *b*).

3. That as animal and vegetable Subſtances are reſolvable into the ſame Principles *b*), there is no Neceſſity for making more than two Diſtinctions or Claſſes of chemical Principles, *viz* the Vegetable and Mineral; which ſeem to differ chiefly in this, that the metallic Species of Minerals may afford a running Mercury, whereas the vegetable and ſimple mineral Species will not.

4. That the different Combinations of theſe five chemical Principles make all that vaſt Variety of natural and artifical Bodies, which have hitherto been analyſed by the Fire; the Difference of theſe Bodies appearing to ariſe from the different Proportions wherein theſe Principles are mixed. Whence, unleſs we except the Air, there ſeems no Neceſſity for introducing a larger Number of Principles, to account chemically for all the various Phænomena of Nature and Art.

5. That the correſpondent animal and vegetable Principles may in many Caſes be uſed for one another; ſo as to render volatile Salts and Oils cheaper, and leſſen the Expence attending their Uſe in particular Arts and Trades *b*).

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a) See the whole Lecture, *paſſim*.
b) See *Exp.* I. II.

6. That in order to leſſen the Trouble and Expence of procuring the volatile Salts of animal Subjects, theſe Subjects ſhould be firſt purged of their Oil and unctuous Parts by boiling in Water: after which they may be made to afford volatile Salts and Spirits, as pure as unboiled Hartſhorn, or purer *a*). But care muſt be taken not to boil the Subject too long, otherwiſe a Jelly will alſo be drawn out of it; which Jelly plentifully contains the Matter of the volatile Salt.

7. That the unrectified volatile Salts of vegetable and animal Subſtances are true *Sales volatiles oleoſi*; that according to the Difference of the Oil abounding in them, they are properly diſtinguiſhed into Salt of Hartſhorn, Salt of Ox bone, Salt of human Blood, of Silk *&c.* But that when theſe Oils are totally ſeparated from them, they become one and the ſame undiſtinguiſhable volatile Salt *b*).

8. That the ſo called *volatile Spirits* of vegetable and animal Subſtances, conſiſt only of a large Proportion of Water, impregnated with ſome of the volatile Oil and Salt of the Subjects; and that they may accordingly be reſolved by Rectification into theſe three Principles; ſo that there is no Neceſſity for introducing a ſpirituous Principle *b*).

9. That it is the Admixture of Oil which gives the Colour to volatile Salts and volatile Spirits; for when this Oil is totally ſeparated from them, the Salt is permanently white, and the Spirit pellucid *c*).

a) See *Exp.* II.

b) See *Exp.* I, II.

c) See *Exp.* II.

10. That volatile Salts are obtainable from all Kinds of Land Animals, the amphibious and ſubterraneous Tribes, Birds, Fiſh, and Reptiles; from alkaline Vegetables without Putrefaction; from other Vegetables after Putrefaction; from Soot, Horns, Hoofs, and all refuſe animal and vegetable Matters, ſuch as the Pith of Horns, Urine, the Blood of Slaughter-houſes, *&c.* and that as pure and perfect as from Hartſhorn: Which affords a Rule for making volatile Alkalies and Sal-Ammoniac cheap in *England.*

11. That elementary Earth, a Subſtance fixed and of itſelf unalterable in the Fire, Air, or Water, conſtitutes the firm Baſis, or Skeleton, of all animal and vegetable Subſtances; and that Water, Salt, and Oil mixed, and wedged betwixt the Particles of this Earth, conſtitute all animal and vegetable Subſtances *a*).

12. That there is only one Kind of volatile alkaline Salt, when reduced to abſolute Purity; the apparent Difference betwixt the volatile Salts depending entirely upon the different Oils wherewith they are mixed *b*).

13. That by endeavouring to purify the chemical Principles too high, we do but deſtroy their Natures *c*), or loſe the Properties whereby they produce their ſpecific Effects. Thus Oils are, by numerous repeated Diſtillations, loſt in the form of Oils, and turned into Earths; volatile Salts fly away in repeated Sublimation; and fixed Salts turn to Earth by repeated Solution and Filtration *d*).

14. That animal Bodies naturally contain no fixed Salt, tho' the acid Vegetables, which are

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a) See *Exp.* I, II.

b) See *Exp.* I, II. See alſo hereafter the Lecture upon *Oils.*

c) See *Exp.* I, II.

d) See Mr. *Boyle*'s *Sceptical Chemiſt.*

uſed as Food, contain it plentifully *a*). Whence there is lodged in the Body a Power of converting the Matter of fixed Salt into the Matter of volatile Salt.

15. That the volatile animal Salts, and the fixed vegetable Salts, differ chiefly with regard to their Volatility and Fixedneſs, and the Effects thereon depending; but agree in other Reſpects. Thus they both make an Effervеſcence, and turn neutral, when ſaturated with Acids; they are both corroſive, hot and fiery, *&c. a*).

16. That a principal Reaſon of the Difficulties attending the Analyſis of Bodies, is the natural Affinity, or Relation, which ſome of the chemical Principles have to others; whence they cohere ſtrongly together, ſo as not to be well ſeparated pure *b*). Thus part of the volatile Oil of Animals uſually riſes with the ſame degree of Heat as the volatile Salt, and intimately mixes therewith, *&c*: Whence, to improve Chemiſtry, we ſhould ſeek out for other analyſing Powers beſides Fire. And ſuch an one in the preſent Caſe is Water; which imbibing the volatile Salt, more ſtrongly than it does the Oil, thus makes a more perfect Separation; whereas Fire chiefly acts as an Analyſer, when there is a conſiderable Difference between the Volatility of Bodies; as in a Mixture of Water, Alcohol, and volatile Salt, all which riſe ſeparately after one another; the volatile Salt firſt, the Alcohol next, and the Water laſt.

17. That the Mercuries of Metals may be real things, and procurable different Ways; and that poſſibly theſe Mercuries, or the common running Mercury, may be convertible into Me-

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a) See *Exp.* I, II.
b) See *Exp.* I, II, III.

tal. But this Matter requires a farther Examination, and ſhould be brought under the direct Evidence of Senſe *a).*

18. Laſtly, that there are certain Inſtruments and chemical Operations, which though little attended to may afford great Light to the Underſtanding, and prove highly advantageous in chemical Philoſophy and Arts: we inſtance, for the preſent, the Mercurification of Metals, the powerful Furnace of the Sun, the artificial Uſe of the common Elements, *&c. a)* all which we recommend to the farther conſideration of chemical Philoſophers.

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a) See *Exp.* III.

LECTURE IX.

CONTAINING

Synthetical Chemiſtry; *or, the Art of Recompoſing Bodies.*

The Subject. 1. IN our laſt Lecture we endeavoured to explain what the more intelligent Chemiſts underſtand by *analytical Chemiſtry*, or the Reſolution of Bodies; in the preſent we propoſe to give ſome Inſtances of Recompoſition, or the compounding of Bodies from their ſeparated Parts or Principles, ſo as to compoſe the Original whole again. This indeed is extremely difficult to effect univerſally; yet it may be done in ſome caſes ſo accurately, that the recompoſed Body ſhall be perfectly undiſtinguiſhable, by the Senſes, from that which had never been ſeparated by the Fire. And if the Art of Chemiſtry were perfect it would be able thus to recompoſe, at leaſt in ſome tolerable manner, all the Bodies it divides. At preſent it is far from this Perfection, eſpecially in the vegetable and animal Kingdoms; where, by reaſon of the vaſcular Texture of the Parts, ſuch a Recompoſition ſeems almoſt impracticable, unleſs the natural or organical Structure be ſome way or other preſerved, or artificially imitated. We are therefore carefully to diſtinguiſh betwixt the Regeneration of organized, and the Regeneration of unorganized Bodies. As the latter is much the more ſimple and eaſy, we ſhall begin with that, and aſcend by degrees to the more complex Kinds; ſo as to ſhew where this Regeneration may be rationally expected, and where it is leſs to be hoped for; together with the ways of carrying this Part of Chemiſtry to greater Perfection.

2. This *Synthetical Chemiſtry*, taken in the ſtrict Senſe, for the Recompoſition of Bodies from their own Principles, is rather of philoſophical than ordinary Uſe. And it will doubtleſs be aſked, to what Purpoſe do we ſtudiouſly endeavour to recover thoſe Bodies by Art, which Nature affords us in plenty? We anſwer, it would ſhew an extreme Perfection and Power in Chemiſtry to be able to do this, and prove, either that Bodies might be taken to pieces by the Fire, without altering or injuring their natural Parts, or at leaſt that any accidental Alteration brought upon them by the Analyſis, might eaſily be rectified or aboliſhed by a Recompoſition. *Synthetical Chemiſtry.*

3. But here we are to guard againſt a Fallacy: for ſuppoſing the Art of Chemiſtry ſo far advanced as to reinſtate Bodies after their Analyſis, we muſt not thence conclude that Nature originally uſes the ſame Means to compoſe them. The Ways ſhe uſes for this Purpoſe would ſtill be a new Enquiry, and ought to be diligently proſecuted, for the farther Improvement of *Philoſophical Chemiſtry.*

4. Our firſt Example of Recompoſition is taken from Nitre, the ſecond from Brandy, the third from Cinnabar, and the laſt from Bone.

EXPERIMENT I.

The Regeneration, or Recompoſition of Nitre, from its own acid Spirit and fixed Alkali.

5. We took two Pounds of refined Salt-Petre reduced to Powder, and putting it into a Glaſs-Retort *Nitre analyſed; or reduced to a Spirit.*

Retort poured upon it a third of its own Weight of rectified Oil of Vitriol; then placing the Retort in a Sand-heat, and luting on a large Receiver, we diſtilled with degrees of Fire, up to the higheſt that Sand would give. Then ſuffering all to cool, we thus obtained a pure and ſtrong *Spirit of Nitre*; which came over in red Fumes, and cannot, by any Experiment, be found to participate of the Oil of Vitriol uſed in its Preparation.

And a fixed Salt. 6. On the other hand, we took a Pound of purified Nitre reduced to Powder, and melting it in an earthen Crucible, caſt little pieces of Charcoal into it ſucceſſively, till the Deflagration ceaſed, and the Salt at the Bottom of the Crucible appeared ſluggiſh, or would no longer keep fluid, with that Degree of Heat which melted it before. Then increaſing the Fire, ſo as to make the Salt run again, we poured it out upon a clean metalline Plate, where it congeal'd into a Subſtance called *fixed Nitre*.

7. And thus, at two different Operations, we reſolved the ſame Subject, Nitre, into two very different Parts; which being put together again, after a proper Manner, conſtitute the original Salt again, in all its Forms.

Recompoſed. 8. For if the alkaline Solution of fixed Nitre in Water, be exactly ſaturated with the acid Spirit of Nitre, till no more Effervefcence appears, and yet the Mixture be not made alkaline; this compound Liquor will, by ſtanding, ſhoot into true and perfect Cryſtals of Nitre, as we found upon Trial. And the Experiment ſucceeds no leſs, if any other fixed alkaline Salt, as that of Tartar, Pot-aſh, *&c.* be uſed inſtead of fixed Nitre.

9. And in the ſame manner may common Salt be regenerated from any fixed alkaline Salt,

and the acid Spirit of Sea-Salt; or Alum, from any fixed alkaline Salt and Spirit of Alum; ſo as to afford us Inſtances of the juſteſt Recompoſition perhaps hitherto known in Chemiſtry.

Uſes. 10. It is remarkable in this Experiment, that the two Subſtances which compoſe the Nitre are extremely different; the one being highly odorous and volatile, the other inodorous and fixed; the one a violent Acid, the other a violent Alkali; but upon mixing, they unite into a neutral Salt, of the very ſame Nature and Properties with that which afforded them.

11. From this Experiment ſome have ventured to affirm that Nitre is naturally generated in the ſame manner; but this ſhould not be allowed till it is ſhewn that ſuch an Acid and ſuch an Alkali are to be found diſtinct in the places where Nitre grows. And we cannot too well remember, that there may be ſeveral phyſical Ways of effecting the ſame Thing; all which Ways are not to be preſumed, but ſought.

12. To this Claſs of artificial Recompoſitions may be added the Reproduction of Sulphurs and Vitriols; tho' the Experiments do not commonly ſucceed in Perfection. Indeed, as we above obſerved that the Thing itſelf is chiefly of philoſophical Uſe, for that Reaſon very few have endeavoured to proſecute it.

13. In our preſent Experiment we may obſerve that the Nitre, tho' in both Caſes it ſuffers a great Violence of Fire, is neither ſcorched nor rendered empyreumatical; which in other Caſes, where the Subject is more oily, ſeems a principal Cauſe of the Difficulties found in the regeneration of Bodies; particularly ſuch as Sugar, Turpentine, Amber, *&c.* Whence we are directed to analyſe theſe unctuous Bodies, with ſuch a degree of Heat as ſhall not ſcorch their Oil, if we de-

ſire to recompoſe them; or elſe to find out ſome more proper Analyſer for them than the Fire; ſuch as particular Solvents, capable of ſeparating, and others of reuniting their component Parts, without having this deſtructive Effect.

14. The Solvents here intimated might have conſiderable Uſes, if a competent Set of them were diſcovered, as directly tending to the Improvement both of *analytical* and *ſynthetical Chemiſtry*. Thus Water in ſome Caſes is a better Analyſer than Fire, as we ſee particularly in the ſeparating of Salts from Earths; and thus ſome Chemiſts are ſaid to have a Method of recovering analyſed Amber, or Amber diſtilled for its Salt and Oil; and that by means, not of the Fire, but of an artificial compound Salt; the Inſtances of which Kind ſhould be collected.

EXPERIMENT II.

Brandy reſolved into its component Parts, and recompoſed.

Brandy analyſed. 15. (1.) To a Pint of Brandy we added half a Pound of dry Salt of Tartar, then ſet the containing Glaſs in a gentle Heat of Sand; where we obſerved the Salt to diſſolve into a Liquor, by attracting to itſelf the Water of the Brandy, leaving a Spirit of Wine floating on the top. This Spirit we decanted upon a little more dry Salt of Tartar, and found that this ſecond Salt ſcarce relented. Then pouring the Spirit into a Glaſs Receiver, we diſtilled it gently over, and thus obtained a highly rectified Spirit of Wine. (2.) In the ſame manner we diſtilled the ſaline Solution left behind upon decanting the Spirit, and thus obtained the Water of the Brandy in conſiderable Purity, leaving the Salt of Tartar behind, in a dry Form. (3.) In the laſt Place, we mixed the Spirit and the Water together, and directly found the Brandy recompoſed, without any conſiderable Alteration. *And recompoſed.*

16. The Separation and Recompoſition is however leſs exact in the preſent, than in the preceding Caſe; becauſe ſome ſmall Part of the Salt will always come over in Diſtillation, both with the Spirit and with the Water: but when the Experiment is performed in Perfection, it may paſs for a tolerably exact Recompoſition.

17. To this Claſs may be added the Recompoſition of Wine, after its Spirit or Brandy has been diſtilled from it, and the Recompoſition of Vinegar from its Spirit and *Reſiduum*. Though both require a new Fret, or ſlight Fermentation. Yet if the Operation be dextrouſly performed, the Recompoſition appears to be juſt and perfect. To render the Operation perfect in either Caſe, we recommend the Uſe of a proper intermediate Subſtance, either fermentable, or actually in a fermenting State; ſuch as a little new Wine, Sugar, Juice of the Grape, or the like: for theſe Subſtances coming to work in the Liquor, lay hold both of their aqueous, ſpirituous, and ſaline Parts; ſo as to bring them into the State of Mixture or Arrangement, on which their Perfection, as Wines and Vinegars, depends. And how far this Method of Recompoſition may be extended ſeems hitherto little conſidered. *The Experiment extended.*

18. In our preſent Experiment for the Recompoſition of Brandy, there are only two conſtituent Parts concerned, *viz.* Alcohol and Phlegm; which renders the Separation and Combination ſo much the eaſier and the more exact: nor is there any Occaſion here for an intermediate Subſtance, to procure, or recover, the natural Union; becauſe Alcohol readily mixes with Water, barely

by ſhaking, and that as intimately as is neceſſary to the Conſtitution of Brandy.

19. In Imitation of this Experiment, it is proper to enquire what other Bodies may be perfectly ſeparated into different Parts by the Way of Menſtruum, Abſorbent, or Precipitant; ſo as to leave the ſeparated Matters unaltered in their Natures, and fit to compoſe the original Subſtance again. This Enquiry depends upon finding out the ſecret Relations which exiſt between particular Bodies; and theſe Relations can only be diſcovered by particular Trials *a*).

Farther Uſes. 20. This Experiment ſhews an uſeful Method of obtaining Spirit of Wine from Brandy, without Diſtillation, which may be practiſed to advantage in the large Way of Buſineſs; *viz.* by adding Pot-aſh to the Brandy once diſtilled, and brought to the Size commonly called *three Fifths*, that is, three Parts Alcohol and two of Water: For the Pot-aſh ſo employed is eaſily recoverable without much loſs, barely by boiling the Lixivium in an Iron Pot; by which Means being dried it will ſerve for the ſame Purpoſe again. This ſlight Experiment has proved of eminent Service, where large Parcels of Brandies have been to be rectified in a ſmall Compaſs of Time.

EXPERIMENT III.

Cinnabar recompoſed, by the Union of its two component Parts, Sulphur *and* Mercury.

Cinnabar recompoſ'd. 21. Having found, in our laſt Lecture, that native Cinnabar is compoſed of Sulphur and Mercury *b*), we took four Ounces of common Brim-

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a) See M. *Geoffroy*'s Paper to this Purpoſe in the *French Memoirs.*

b) See *Lect.* VIII. *Exp.* III.

ſtone, and melting it in a earthen Pan, over a dull Fire, added by Degrees twelve Ounces of crude Quickſilver, firſt made warm, and ſtirred them well together, till no Globules of the Quickſilver appeared; then ſuffering the Maſs to cool, we reduced it to Powder, and ſublimed it, with a proper Degree of Heat; and thus obtained an artificial Cinnabar, which being ground fine, and compared with the natural, appeared undiſtinguiſhable from it.

22. The regenerated or artificial Cinnabar has not the ſtony Form of the native; this Form being accidental in the Mine, and determined by the Circumſtances of the Place, as the Form of the regenerated Cinnabar is by the Figure and Make of the Veſſel wherein it was ſublimed. But if the two be compared together, in all other Reſpects there appears no Difference, when the Operation is juſtly performed. *Uſes.*

23. This Experiment ſhews us the common Method of preparing artificial Cinnabar, which may, in the large Way of Buſineſs, be thus ſublimed in a tall earthen, or coated Body, with its Head well luted on, and ſo placed in a Sand-Heat as to touch the Bottom of the Iron-Pot, whilſt the Sand riſes above the Matter contained in the Veſſel. And here it is a principal Caution to uſe a briſk Fire, that the Operation may be finiſhed in three or four Hours Time. And probably, if only one Part of Sulphur be uſed to about four Parts of Quickſilver, the Cinnabar will be the finer; for about thirteen Ounces of running Mercury may be recovered from a Pound of native Cinnabar.

24. And thus we have an Inſtance of a perfect Recompoſition, in a metallic Body, or Subject of the mineral Kingdom: for the Experiment ſucceeds alike, when the Sulphur and Mercury

of native Cinnabar is uſed *a*). To this Claſs might be referred the Reduction, or Recovery, of all the Calces of Metals to a metallic Form again, by the Addition of any inflammable Matter, which they loſe in their Calcination; as alſo the Regeneration of Antimony, by melting its Regulus with Sulphur; the Regeneration of Ores, by melting their Metals with Sulphur, ſtony Earths, *&c.* ſo as to mix them again; and all other Inſtances of this Kind.

25. The preſent Experiment is of conſiderable uſe, particularly in natural Philoſophy, and Metallurgy; as it ſhews us that a very large Proportion of fluid Mercury may, by Means of a very ſmall one of Sulphur, be fixed into a Body of a ſtony Hardneſs, ſuch as the native Cinnabar. Whence we ſhould not be over-haſty to conclude that Mercury cannot aſſume a metalline Form *a*). Some metallurgical Chemiſts contend, that Mercury is nothing elſe but a Metal, overdoſed with that Part which gives ductility and ſoftneſs, which remarkably belong to all the Metals when amalgamated with Mercury. In ſhort, whoever duly lays together all the Properties of Mercury, may perhaps find Cauſe to allow it a metallic Nature *b*).

EXPERIMENT IV.

An Attempt to recompoſe Bone from its Aſhes.

Bone recompoſed. 26. (1.) We took a large Ox-Bone, and made a ſtrong Jelly thereof with Water in the Digeſtor *c*); then (2.) in an open Fire we burnt and calcined the Bone to whiteneſs, without deſtroying its

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a) See *Lect.* VIII. *Exp.* III.
b) See the Place laſt quoted.
c) See *Lect.* VI. *Exp.* VII.

its external Figure; ſo that in other reſpects the Bone was reduced to mere Aſhes, or ſeparated from the Principles of Water, Oil, and Salt, which it originally contained. In this ſtate we found it extremely brittle and crumbly; but (3.) putting it into the Digeſtor again with the Gelly, and warming them together over the Fire for ſome time, then taking the Bone out, and ſuffering it to dry in the open Air, we found that it gradually hardened, and recovered, in ſome tolerable Degree, the Appearance, or Colour and Conſiſtence, of the natural Bone.

27. Gelly, by an Analyſis, is found to yield the ſame Principles as Bone itſelf *a)*; or to contain the matter, not only of Water, but of Salt and Oil, and a little Earth: ſo that to uſe this Gelly, is the ſame thing as to uſe the Water, Salt and Oil; all which being thus together ſoaked into the Skeleton of the Bone, reſtores it in ſome Degree to its natural State.

28. But to uſe the direct volatile Salt and Oil of the Bone for this Purpoſe, were to uſe two things which did not exiſt in thoſe Forms in the Bone; for to ſeparate the volatile Salt and Oil from Bone, requires a much greater Degree of Heat than that natural to an animal Body; ſo that they are never thus ſeparated in the Body, whilſt that remains in its natural State. Yet a Degree of Hardneſs (with Diſcoloration, on account of the black and ſcorched Oil of the Subject) may be given to Bone-Aſhes by the ſeparated Oil, or even by Water, as we ſee in Teſts.

29. We were farther encouraged to uſe the Gelly of the Bone in this Experiment, from obſerving by repeated Operations in the Digeſtor *b)*, that all the active Principles of the Bone might

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a) See *Lect.* VIII. *Exp.* II.

b) See *Lect.* VI *Exp.* VII.

be got out and united with the Water added to extract them; ſo as to leave nothing but a little Earth behind, reſembling the Aſhes left upon a dry Calcination in a violent Fire. Whence we are plainly inſtructed in the Nature of animal Gelly, with its Uſes to the Body. And hence alſo we learn the Nature of Mucilages, Size, Glues, and may underſtand many things relating to Medicine, the animal Oeconomy and Arts.

Uſes. 30. This Experiment might be rendered more ſucceſsful, if we could procure the tenacious Glue or Cement, which obſtinately remains in the Pores of the Bone, even tho' long detained in the Fire. This Glue ſeems to be an intermediate Subſtance, of a middle nature betwixt Gelly and elementary Earth; whence it were proper to try whether, by grinding the elementary Earth fine and digeſting it with Gelly, ſome ſuch tenacious Glue could not be procured. This alſo might open the way to a Hiſtory of Glues, which is extreamly wanted in Chemiſtry, natural Philoſophy, and Arts.

31. If a promiſcous Maſs of elementary Earth be uſed, inſtead of that which retains its natural vaſcular Form, a Kind of *Callus* will be thus produced, inſtead of a regular Bone. Whence we may be enabled to judge of the Nature of the *Callus* formed in the Bones of Animals.

32. After the manner of our preſent Experiment, we might alſo attempt to recompoſe vegetable Subjects. But before any thing of this Kind is done to Perfection, Chemiſtry will require the Aſſiſtance of mechanical Contrivance, and many Improvements from the Anatomy of Plants; particularly it muſt learn to preſerve the native Spirits of Vegetables, upon the Analyſis, or elſe the artificial ways of imitating and introducing ſuch Spirits into the Subject. Theſe Spi-

rits are extreamely apt to fly off with Heat, yet may in good Meaſure be collected and preſerved by Art. And unleſs they are thus preſerved, the Subjects will want their native Taſtes and Odours, which depend upon theſe Spirits, or ſubtile, volatile Matters.

Perfect Recompoſition.

33. The higheſt Degree of Recompoſition is, when a Body is perfectly reſolved into its Principles, (ſuppoſe a Vegetable Subject into Water, Salt, Oil, and Earth) and theſe are again put together, ſo as to form a Subject undiſtinguiſhable from the Original. In order to attain this Perfection, let the thing be firſt tried in ſimilar, unorganized Bodies; as Glaſs, Turpentine, Amber, Vegetable Juices, Wines, Sulphurs, Ores, *&c.* proceeding by ſlow Degrees, up to the more diſſimilar and organical Bodies; ſuch as vegetable and animal Subjects.

34. We have ſeen that, in many Caſes, a true Reſolution and Recompoſition are practicable; and as Chemiſtry improves, the Buſineſs of *Analyſis* and *Syntheſis* muſt likewiſe improve.

The Imperfect uſeful.

35. But let it be obſerved, that the Power of Chemiſtry is not limited to the Buſineſs of juſt Reſolutions and Recompoſitions: it can produce numberleſs Effects without going to this Exactneſs. Thus it already analyſes and recompoſes, or ſeparates and mixes, all the natural and artificial Bodies, in its own imperfect manner. And thus it has furniſhed us with all Chemical Medicines; as Tinctures, Extracts, Spirits, Oils, Waters, Eſſences, *&c.* and the ſeveral Commodities of Sugar, Wine, Alum, Salt, Pot-Aſh, Aqua-Fortis, Oil of Vitriol, Soap, Glaſs, *&c.* *&c.* *&c.* For without attempting a perfect Separation or Recompoſition of the chemical Principles, a groſs Separation or Mixture of two or three of them will frequently afford very uſe-

ful Subſtances; ſo that Chemiſtry, tho' it remains imperfect, is ſtill highly ſerviceable.

AXIOMS *and* CANONS.

1. We learn from the preceding Enquiry, that we cannot ſafely conclude Bodies to have been originally compoſed of the ſame Principles, into which the Fire reſolves them *a)*.

2. That as the Fire, in many Caſes, proves a juſt Analyſer, and reſolves Bodies into their conſtituent Parts, without Alteration; ſo, in others, it quite perverts and changes their Nature and Properties; eſpecially by ſcorching the Oil of a Subject which abounds therewith *b)*.

3. That the perfect Regeneration of Bodies can take place in ſuch Caſes only where the Fire, or other Inſtrument, is a true Analyſer, without adding any extraneous thing of its own, or any way altering or ſubverting the Nature of the Parts ſeparated *c)*.

4. That the Buſineſs of Recompoſition is to be diſtinguiſhed into three Kinds, *viz.* mineral, vegetable, and animal, differing in Degree of Facility; the mineral Kind being the eaſieſt, and therefore to be firſt cultivated, in order to improve *Synthetical* Chemiſtry, and render it more advantageouſly practicable in organical Bodies *d)*.

5. That *Synthetical Chemiſtry* is more imperfect than the *Analytical*; or that the preſent Chemiſtry divides natural Bodies more perfectly than it puts them together again, for want of more proper Analyſers than Fire, and more

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a) See §. 3. & *Exp.* I.
b) See *Exp.* I. See alſo *Lect.* VIII, *Exp.* II.
c) See *Exp.* I, II, III, IV.
d) See *Exp.* I, III, IV.

ſuitable Methods and Menſtruums than are hitherto diſcovered *a)*.

6. That a new Compoſition is uſually made in every chemical Reſolution. Thus when Nitre is ſeparated into an acid Spirit, its fixed Salt remains compounded with the Oil of Vitriol *b*). When Mercury is ſeparated from the Sulphur in Cinnabar, the Sulphur remains united with the Quick-Lime, or Iron-Filings *c)*. When Water is ſeparated from Brandy, the Water unites with the fixed Salt, and leaves the Spirit to float ſeparate *d)*. And this appears to be generally the Caſe; ſo that the Separation is made by ſome intermediate Body, which unites with one Part, and not with the other of the Subject *e)*. Whence we are directed to find out the *Mediums of Mixture* and *Recompoſition*, as well as of *Separation*, in order to perfect *Analytical* and *Synthetical Chemiſtry*.

7. That Bodies endowed with a native Spirit are hard to recompoſe, unleſs this Spirit be ſome way artificially preſerved *f)*. Thus for Inſtance, Seeds, Roots, Flowers, *&c.* may be dried in cloſe Glaſſes, with blind Heads, ſet upon a gentle Sand-Heat; then taking the Subject out, and ſeparating its Principles, the Oils and Salts being afterwards impregnated with the native Spirit of the Subject, remaining in the Blind-Heads, may thus ſerve to recompoſe the whole in ſome tolerable Degree.

8. That animal Gelly is a Mixture of all the Principles of an animal Subject, *viz.* much Water,

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a) See the preceding Lecture, *paſſim*.
b) See *Exp.* I.
c) See *Lect.* VIII. *Exp.* III.
d) See *Exp.* II.
e) See *Exp.* I, II, III, IV.
f) See §. 31. *&c.*

a moderate Proportion of Oil and Salt, and a little Earth *a*). Whence we learn the phyſical Cauſe why Gelly is nutrimental; why animal Subſtances ſo much abound therewith; its Uſes in the Body; its reſtorative Nature, *&c.* And hence we have a Foundation for the natural and experimental Hiſtory of Gellies, Size, Glues, *&c. b*).

9. That the Buſineſs of Analytical Chemiſtry is deficient, which ought to afford the Rule of operating to Synthetical Chemiſtry *c*). Thus moſt of the Analytical Operations hitherto performed, are but ſuperficial Attempts to enter and open the Subſtances of natural Bodies; for which purpoſe, in ſome Caſes, long Digeſtions, repeated Reverberations, vaporous Mixture, exquiſite Triture, continued Fuſion, ſubtile Precipitation, *&c.* are required. Whence the Improvement of Synthetical Chemiſtry will greatly depend upon the Improvement of the Analytical.

10. That another way of improving *Synthetical Chemiſtry* is carefully to obſerve what Steps Nature takes in ſupplying and recruiting the Bodies of vegetable, animal, and mineral Subſtances; and whether there be any mineral Inſtances of Regeneration in Nature, from the direct Principles themſelves without Addition; or whether this Action be not uſually performed by ſome certain Aſſiſtance within the Power of Art to procure; and particularly what is the Office of the Air, Water, and Fire, in bringing about this natural Operation *d*) in the way of *Fermentation*, *Putrefaction*, *Accretion*, *Nutrition*, and the general Principles of Motion or Life *e*); and whether the

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a) See *Exp.* IV. See alſo *Lect.* VI. *Exp.* VII.

b) See above § 28. See alſo *Lect* VI. *Exp.* VII.

c) See *Lect.* VIII. and the preſent *paſſim.*

d) See *Exp.* I.

e) See *Lect.* VII. *paſſim.*

the common Elements do not contribute ſome Part of their Subſtance, as well as Energy, in the Change *. From ſuch an Enquiry, conducted in a regular Manner, it ſhould ſeem that ſome capital *Canons* might be derived for improving this grand Part of operative Philoſophy.

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* See the preceding Lectures upon the Elements.

LECTURE X.

CONTAINING

The Curation of Vegetables; or the Means of preparing and fitting vegetable Subjects for various Uſes, viz. Brewing, Diſtilling, Vinegar-Making, *&c.*

The Subject. 1. WE are now proceeding to examine into the Nature of Seminal Vegetation, and the Curation or Preſervation of Vegetables, with a View to the Improvement of Chemiſtry and the Arts thereon depending.

Its Extent. 2. The Subject is of large Extent, and if duly proſecuted, might tend to the Enrichment of the preſent Arts, or the Diſcovery of new ones. For on regulating the Growth, and on the Curation of Vegetable Productions, depends the Perfection of Corn, Wines, Malt, Bread, Sugar, Tobacco, Spice, Drugs, Simples, Dying-Stuffs, and the like. And new Diſcoveries either in Vegetation, or Curation, might eaſily introduce new Trades; as has been the Caſe in Sugar, Tobacco, Wines, Spirits, *&c.*

The Procedure. 3. By Experiments in Vegetation, we here propoſe to ſhew the Methods of regulating or conducting this natural Power for the Service of Arts; by directing it to anſwer particular Ends. Thus by ſtopping ſhort towards the Beginning of Vegetation in Barley, we procure Malt; and by permitting the Grapes to hang till they grow not only ripe, but almoſt dry, upon the Vine, we procure rich ſweet Wines. And thus we may ſtop Vegetation at any Period, or continue it longer than ordinary, according as the Occaſions of different Arts require.

Curation what.

4. By Experiments in *Curation* we would ſhew the Methods of collecting, preparing, and ſecuring vegetable Commodities; ſo as that they may long remain ſound, perfect, and fit for Service. And thus our preſent Lecture will conſiſt of two Parts; the one relating to the ways of *growing* Vegetables, according to the Uſes for which they are intended, and the other to the *gathering* and *preſerving* them, ſo as to have them conſtantly ready at hand, when they come to be required in Uſe.

The Deſign of the Experiments.

5. Our firſt Experiment therefore is calculated to ſhew the Method of ſtopping the natural Proceſs of Vegetation in the Seed; ſo as to prepare Grain, Pulſe, Nuts, Maſt, and Roots, for the making of Beer, Vinegar, and Spirits. Our ſecond is deſigned to ſhew the Method of curing both fermented and unfermented vegetable Juices, ſo as to make them keep ſound and good for ſeveral Years. Our third Experiment tends to ſhew the Method of curing vegetable Juices by Decoction, or Inſpiſſation, for the Service of Brewing and Diſtilling. And our fourth and laſt Experiment will ſhew the Method of curing Yeaſt, the Flowers of Wine, and Wine-Lees, for the Service of ſeveral Arts. Theſe Experiments now follow in order.

EXPERIMENT I.

The Method of ſtopping the Natural Proceſs of Vegetation, with a view to Malting; or the Preparation of Grain, Seeds, Pulſe, Nuts, Maſt, and Roots, for the making of Beers, Vinegars, and Spirits.

6. We

Malting.

6. We plucked up a Parcel of Garden-Beans, after they had been ſuffered to lie in the Ground about ſix Weeks in the Winter-Seaſon; and found each Bean beginning to ſplit, or ſeparate, into its two *Lobes*, whilſt the *Radicle* was ſhot out ſome Inches downwards, and had begun to take Root in the Ground; the *Plume* alſo, which becomes the Stalk of the Bean, being riſen to the height of two Inches. In this ſtate we dried a few of theſe over a clear Fire, and thus found them turned to a Kind of Bean-Malt, that taſted ſweetiſh, bit mealy betwixt the Teeth, and diſſolved freely in warm Water; ſo as to afford a Wort, fit for fermentig with Yeaſt into a Kind of Beer or Ale.

7. This Experiment inſtructs us in the ordinary Proceſs of Malting; which, in the Caſe of Barley, is conformable hereto, and in the Caſe of Malting *Indian Corn* is the Proceſs itſelf *.

The Proceſs of Malting.

8. In making Malt from Barley, the uſual Method is to ſteep the Grain in a ſufficient Quantity of Water, for two or three Days, till it ſwells, becomes plump, ſomewhat tender, and tinges the Water of a bright brown, or reddiſh Colour. Then this Water being drained away, the Barley is removed from the ſteeping Ciſtern to a Floor, where it is thrown into what they call the *Wet-Couch*; that is, an even Heap, riſing to the Height of about two Foot. In this *Wet-Couch* the capital Part of the Operation is performed; for here the Barley ſpontaneouſlly heats, and begins to grow, exactly in the ſame manner as in our preſent Example of Beans; ſhooting out firſt the *Radicle*, and then if ſuffered to continue, the *Plume*, *Spire*, or *Blade*. But the Proceſs is to be ſtopped ſhort at the Eruption of the Radicle,

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* See below §. 10. See alſo ſome Experiments to this Purpoſe in the *Philoſophical Tranſactions.*

otherwiſe the Malt would be ſpoiled. The way to ſtop it is, to ſpread this Wet-Couch thin over a large Floor, and keep it turning once in four or five hours, for the ſpace of two Days, laying it ſomewhat thicker each time. After this, the Malt is again thrown in a large Heap, and there ſuffered to grow ſenſibly hot to the Hand, as it uſually will in twenty or thirty Hours time; then being ſpread abroad again and cooled, it is thrown upon the Kiln, to be dried criſp without ſcorching.

How managed to beſt advantage.

9. And this is the general Proceſs of Malting, wherein almoſt every Maltſter has his ſecret or particular way of working. But to render the Operation perfect, the following Cautions muſt be obſerved: (1.) That the Barley be newly thraſhed, or at leaſt newly winnowed; (2.) That it be not mixed or made up of different Sorts; (3.) That it be not over ſteeped in the Ciſtern, or ly there ſo long as to make it ſoft; (4.) That it be well drained; (5.) That it be carefully looked after in the Wet-Couch, ſo as to ſtop the firſt Tendency of the Blade to ſhooting; (6.) To turn the Wet-Couch inſide outermoſt if the Barley *comes* (that is, ſhoots) more in the middle than on the ſides; (7.) To keep it duly turning after it is out of the Wet-Couch; (8.) To give it the proper heating in the dry Heap; (9.) To dry and criſp it thoroughly upon the Kiln, but without a fierce Fire, ſo as to be ſeveral Days in drying a Kiln of Pale Malt. If theſe Directions be carefully obſerved, the Malt will always be good.

10. The Method of Malting *Indian-Corn*, or *Virginia Wheat*, is much leſs laborious. For if this Corn be buried two or three Inches deep in the Earth, and covered with the looſe Mould dug up to make room for it, in ten or twelve Days time the Corn will ſprout, and appear like a green

a green Field; at which time being taken up, and waſhed or fanned from its Dirt, it is immediately committed to the Kiln, and by this means it becomes good Malt, exactly as Beans ſo treated would do.

11. It is obſervable of this Corn, that both its Root and Blade muſt ſhoot to a conſiderable length, before it will make Malt. And perhaps this is the Caſe in all large-bodied Grain and Nuts *a)*.

Extended. 12. It might be of Service to transfer this eaſy Experiment to the making of Malt from Barley, Rice, and the other ſmall Grains and Seeds: but the Attempt may be attended with Difficulties; becauſe in the making of Malt, the Barley muſt be ſuffered to grow in its Root only, and not in the Blade; whence it would be difficult, at firſt, to hit the exact time for taking it out of the Ground. And, again, as the Grain is ſo ſmall, it might prove troubleſome to ſeparate it from the Earth or Mould. However, the thing may deſerve to be tried *b)*.

Its Effects, and End. 13. It is a Conſideration of a higher Nature to determine the phyſical Effect procured by Malting, and whether the End may not be obtained by cheaper and leſs laborious Means. The phyſical Difference betwixt malted and unmalted Corn appears to be the Production, or Extrication, of a ſweet ſaccharine Subſtance in the Malt, which is wanting under that form in the Corn. And it is the ſweet Subſtance alone, which we require in

a) It may be worth trying, whether the ſame Proceſs is not, with due Care, applicable to the Malting of Turnips, Potatoes, Carrots, Parſnips, *&c.*

b) And poſſibly ſome Contrivance might be found, by the means of large Hair-Cloths, or otherwiſe, to incloſe the Grain, ſo that the looſe Earth ſhould not mix among it; and at the ſame time an Opportunity be afforded, of commodiouſly examining how far the Barley is *come* at any time after lying.

in Malt for the making of Beer, Ale, Vinegar, and inflammable Spirits *a)*. But even unmalted Corn, duly treated, may be made to afford Beer, Ale, Vinegar, and Spirits: This, therefore, may intimate to us a way of making ſuch Liquors, without the formal Extrication of any remarkably ſweet ſaccharine Subſtance. According to ſome Trials we have made, unmalted Corn affords half the Quantity of inflammable Spirit by Fermentation and Diſtillation, as the ſame Corn would do when malted. And ſuppoſe that unmalted Corn were to be made into a Kind of Dough, or Paſte fermented with Yeaſt, as is uſual for Bread, and then baked; would not this be a cheap Subſtitute for Malting *b)*? At leaſt, it deſerves to be tried, how much Beer, Ale, Vinegar, and Spirit, might be procured this way, compared with that other of Malting.

14. On the other hand, if only a ſweet ſaccharine Subſtance be required in Malt, are there not cheaper and eaſier ways of procuring it than by Malting? Do not many Trees afford ſuch a ſaccharine Juice, by Tapping in the Spring, without prejudicing the Trees? Is not young green Corn itſelf remarkably ſweet; and does not this ſweet Juice enter the Compoſition of the Ear, and there remain fixed, or almoſt loſt in a ſaccharine Form, till recovered by Malting? Here is a Door opened for explaining the Nature of Sweetneſs, and deducing the particular Hiſtory of Sugar. Such a Work, for its Uſefulneſs in Trades and ordinary Life, we wiſh were extant; and till ſome conſiderable Progreſs is made there-

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a) See *Lect.* VII. *Exp.* I, II, IV.

b) They are ſaid to brew after this manner in ſome Countries.

in, the Art of Malting, and all thoſe that depend upon it muſt remain ſhort of perfection.

15. Thoſe, who are diſpoſed to go upon the Enquiry, may pleaſe to compare the Art of Starch-Making with that of Malting, and particularly try whether ſome conſiderable Uſes may not be made of the Refuſe Liquors produced in both Arts. The high-coloured Liquor drawn from the Barley in the ſteeping Ciſtern is a vegetable Tincture, that might, if not by itſelf, yet by being uſed inſtead of Water to ground Malt, be worth fermenting and diſtilling for Spirit; and the Starch-Makers refuſe Liquors have been obſerved to contain a Quantity of inflammable Spirit.

16. Our preſent Experiment may in this reſpect be made general, that it ſhews us there are different times of ſtopping, or preventing, the farther Growth of Vegetables, for the Service of Arts. And this Doctrine may be extended to the forming a Set of general Rules, for gathering the different Parts of Plants, at different Seaſons of the Year, for different Uſes.

Uſes. 17. Thus Roots, for inſtance, to be had perfect, ſhould be gathered and dried in the Spring, before the Leaves are formed; Leaves ſhould be gathered when they are fully opened, but before the Flowers appear; Flowers when they are not fully opened; and ſome, as red Roſes, in the Bud. Seeds are to be gathered when full ripe, and beginning to dry, before they fall ſpontaneouſly; and Trees are generally beſt felled and flawed for their Bark in the Beginning of the Spring. But all this is to be underſtood of the common Uſes of the Subjects; for there are many particular Occaſions, which require them immature. Thus Buckthorn-Berries, ſhould be ripe gathered for making the Syrup, but unripe, for making the Painter's Colour called *Sap-Green.*

EXPERIMENT II.

A Method of Curing both unfermented and fermented vegetable Juices.

Matching or Fumigating with Brimſtone.

18. (1.) We melted Brimſtone in an Iron Ladle, and dipping ſlips of coarſe linnen Cloth therein, made what the Wine-Coopers commonly call Match. (2.) We took a ſlip of this Match, and ſetting one end thereof on fire, put it into the Bung-Hole of a Caſk, which being at firſt looſely ſtopped, ſuffered the Match to burn nearly out. Then the Bung being driven in tight, we ſet the Caſk aſide for an hour or two, and found that this Operation communicated a violently pungent and ſuffocating Scent to the Caſk, with a conſiderable Degree of Acidity, which is the *Gas* and acid Spirit of the Sulphur. We now filled the Caſk with a very ſmall Wine, which had ſcarce finiſhed its Fermentation; and bunging it down tight, we put it in a proper place to clarify.

19. This is the common Method of matching Caſk for Wines, but particularly for Stums. It is an uſeful Experiment; for poor Wines could ſcarce be kept potable a few Months wihout it; nor could Stums be prepared in large quantities by any other Method commonly known.

Stum what.

20. By Stum we underſtand the unfermented Juice of the Grape, ſeveral times racked and drawn from its Sediment, the Caſk being every time thus fumigated with Brimſtone, to prevent the Liquor from fermenting, as it would otherwiſe readily do and ſo become Wine. It is the Fume of the burning Sulphur which thus ſtops all Tendency to Fermentation, and continues the natural Juice of the Grape in a ſweet ſtate, fit to be readily

dily mixed with Wines inſtead of Sugar; for which purpoſe it is very much uſed in *Holland*, and other Countries, as alſo for giving a new *Fret*, or Briſkneſs, to decayed Wines; ſo that very large Quantities of this Stum are annually imported to all Parts along with the Foreign Wines. And after the ſame manner a Stum is prepared in *England* from the Juice of Apples, which ſerves the ordinary purpoſes of the Wine-Cooper.

Inconveniences of Matching. 21. The principal Inconveniences in this Method of matching the Caſk are theſe; (1.) that it communicates a nauſeous ſulphureous Taſte and Smell to the Wine; and (2.) that it is not applicable to red Stums, or red Wines, without greatly impairing, or almoſt deſtroying their Colour; whence the Stums in common Uſe are always white, the Produce of white Grapes. And becauſe this Method of Matching does not ſuit with red Wines, hence it is, that all red Wines are uſually doſed with Brandy in order to preſerve them. And for Wines in general, it might very well ſuffice to burn a little Spirit of Wine in the Caſk; and if they want Strength, or Spirit, to preſerve them ſound, to add Brandy or Spirit of Wine, proportionably. By which means they may be preſerved without any nauſeous Smell, or Taſte, which always attend the Way of matching; tho' matched Wines loſe of their ſulphureous Taſte, and Odour by long keeping. But for Stums, there is no other Way commonly known and practiſed, to preſerve them, but by uſing the Fumes of Sulphur.

The Experiment extended. 22. The Experiment however is almoſt general, and may be applied to advantage in the caſe of all fermented Liquors, and again to unfermented vegetable Juices; ſuch as thoſe of Citrons, Quinces, Oranges, *&c.* which it prevents from running into Fermentation or Putrefaction. And this Effect it ſeems to have, chiefly by ſtiffening the Air, or weakening its natural Elaſticity *. For as all vinous Fermentation is found to generate Air, ſo the burning of Sulphur is found to ſtiffen or deſtroy Air. And hence it ſeems to be, that the Fume of burning Brimſtone readily checks the Fermentation of Liquors; ſo that if a Caſk, by fretting or fermenting, appears ready to burſt its Hoops, a Diſh of burning Brimſtone held under it will ſoon quell the Motion: which is one known Method of checking or ſuppreſſing vinous Fermentation.

EXPERIMENT III.

The Method of curing vegetable Juices by Decoction, or Inſpiſſation.

25. We made an Infuſion of Malt, in the common Manner of Wort for Beer or Ale; then letting it ſtand to clarify, we decanted the clear Liquor, and boiled it over a ſoft Fire to the Conſiſtence of Treacle: in which State it will long keep ſound, or fit for making Beer, Vinegar, or inflammable Spirit. *Wort inſpiſſated.*

24. This Experiment ſhews us a general Way of reducing fermentable Subjects to a ſmall Compaſs, and of ſecuring them againſt external Injuries. Thus a Kind of Treacle from Malt might be procured in cheap Years, for the Service of the Vinegar-maker, the Brewer, and the Diſtiller. The Method is likewiſe applicable to any other ſweet or ſaccharine Juice; as that of Grapes, the Tappings of Trees, the fermentable Juices of Summer Fruits, and of certain ſweet Roots, as Parſnips, &c. *The Experiment extended.*

25. Theſe inſpiſſated Juices, if not boiled too high or ſcorched in the Operation, are eaſily

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* See Mr. *Hale's Vegetable Staticks.*

brought back to a due Degree of Thinneſs with Water, and fermented in the ſame Manner, and for the ſame Purpoſes, as they might have been before they were boiled: So that Beer, Vinegar, or Spirits may be thus commodiouſly procured, at any Time, even in hot Climates; and it ſhould ſeem that Brewers and Diſtillers might alſo reap ſome Advantage from a prudent Uſe of this Expedient.

26. The Wine-Merchant might thus order the Juice of Grapes, or Stum, to be boiled down in Wine Countries, and ſo left fit to be reduced by Water and fermented into Wines in others. And for this Purpoſe the poorer Vintages might ſerve, as well as the rich; excepting only that the Rob, when reduced by Water, would not afford ſo much Wine as the thicker or richer Juices. But the Operation muſt be performed with conſiderable Exactneſs, to make it ſucceed ſo as to produce artificial Wines perfectly like the natural.

27. This Proceſs alſo ſeems applicable to Hops, which in cheap Years, may be thus made into a Kind of Extract, without any Loſs of their valuable Parts; whereby the numerous Contingencies attending that Commodity, might in good Meaſure be prevented. But there would here be Danger of Fraud; becauſe the Extracts of Gentian, Centaury, or other bitter, ſtomachic Vegetables might be mixed with the Extract of Hops, ſo as not to be eaſily diſcovered. Yet perhaps this Inconvenience would not be greater than that generally ſuffered already; for many, no doubt, are well aſſured by Experience, that the Extract of Gentian is a wholeſome Bitter, which might very well ſupply the Place of Hops in Brewing.

28. A Proceſs ſomewhat of this Kind is frequently practiſed in Wine-Countries; *viz.* either

by ſuffering the Grapes to grow almoſt dry upon the Vine; or elſe by boiling down their Juice, till it becomes ſufficiently thick to afford ſuch rich Wines as *Canary* or *Frontignac*; whoſe Strength may be readily imitated by adding a leſs Proportion of Water to the Rob, or inſpiſſated Juice of Grapes, in the Manner above explained *.

29. Before we quit this Proceſs we would recommend it to be tried, upon the Juice that may be eaſily expreſſed from a vegetable Subject commonly thrown away as uſeleſs: we mean the Shells of green Peaſe, which by being barely boiled in Water, communicate a ſaccharine Sweetneſs thereto; ſo that the Liquor has been made into tolerable Drink, and a good Spirit.

EXPERIMENT IV.

A Method of curing Yeaſt, the Flower of Wine, and alſo Wine-Lees, for the Service of Diſtilling, Wine-Making, Vinegar-Making, &c.

30. We took a Quantity of common Ale-Yeaſt, and putting it into a cloſe Canvas Bag, gently ſqueezed out the Moiſture in a Screw-Preſs, till the remaining Matter was left as hard as Clay; and in this State having packed it cloſe in a tight Caſk, and ſecured it well from the Air, it kept freſh and ſound for ſeveral Months; as has been often experienced by others. *Yeaſt cured and preſerved.*

31. This is an Experiment of conſiderable Uſe to Brewers and Diſtillers, who employ very large Quantities of Yeaſt, and yet ſeem in *England* to have no good Method of preſerving it, or raiſing Nurſeries thereof; for Want of which they ſuſtain a conſiderable Loſs. Whereas the Brewers in *Flanders* make a great Profit, by ſupplying the *Uſe.*

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* §. 23—27.

Malt-Diſtillers of *Holland* with Yeaſt, which is rendered laſting and fit for Carriage, after the Manner of our preſent Experiment.

The Experiment extended. 32. The ſame Method is practicable to much greater Advantage in the Yeaſt of Wine, and in Wine-Lees, if they could be imported into *England*. For by this Means we might eaſily imitate the Wines and Brandies of foreign Growths; the Lees and Yeaſt of Wine readily affording an eſſential Oil, by Diſtillation, of which a ſmall Proportion will flavour a large one of Wine or Brandy. But a ſhorter and more perfect Way is to let any taſteleſs, or other proper Wine, fret or ſtand, for ſome Time, upon ſuch Lees, or Wine-Yeaſt, whereby it will to great Advantage acquire the natural Taſte and Flavour of the Wine, to which the Lee, or Yeaſt, belonged.

Perfect Curation what. 33. Thus we have given a few Examples of *Vegetable Curation*, on which the Improvement of ſeveral Arts depends. We cannot go through all the Species of it, for that would be an immenſe Labour; nor are Men hitherto arrived at the perfect Method of preſerving Vegetables in their natural Form, with their Colours, Odours, and other ſenſible Qualities, for any Number of Years. Yet ſomething conſiderable might be done in this Way, by proper Application. Fruits may long be preſerved freſh in Spirit of Wine, firſt well ſaturated with the Skins and tinging Parts of the Fruit. And many of them may be tolerably preſerved in perfectly fermented Liquors, which generate no more Air. The more ſolid Kinds of Subſtances may be commodiouſly cured, by gently drying them in the Sun, Shade, or other ſlack Heat. Thus Peaſe, or Beans, being dried young in a ſlack Oven, in their proper Seaſon, may be boiled green and tender, in the Winter, almoſt like thoſe new gathered. Certain Ways of preſerving Fruits, and other vegetable Subjects, both in a dry and moiſt Form, with Sugar, are now generally known: But there are ſome extraordinary Means of curing ſeveral particular Kinds of Bodies reſerved as Secrets by Artiſts; tho' even theſe might be exceeded, if we had a thorough Knowledge of the preſent Subject. The Deſign might alſo be extended to the animal Kingdom, under the Name of *Animal Curation*; the compleat Art whereof would prove highly uſeful at Sea.

AXIOMS *and* CANONS.

1. We learn from the preceding Enquiry, that Men have Power to ſtop the Courſe of Nature in Vegetation, ſo as to make this Principle anſwer their own particular Ends and Deſigns; whence Arts may receive conſiderable Improvements *a*).

2. That the Art of Malting is farther improveable by a general Acquaintance with the Nature of Vegetation, vegetable Juices, the Art of Fermentation, and the Art of Sugars *b*).

3. That the Labour and Expence attending the Art of Malting may, in ſome Meaſure, be ſaved, by procuring and ſeparating the ſweet Juices of Vegetables as Nature affords them; or by boiling them down to a Treacle or ſaccharine Subſtance *c*).

4. That there are different Seaſons of the Year peculiarly fitted to the collecting or procuring of theſe Juices, and all other vegetable Matters, according as they are required ripe or immature *d*).

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a) See *Exp.* I.
b) See *Exp.* I. II.
c) See *Exp.* I. III.
d) See *Exp.* I.

5. That the Fumes of burning Sulphur have a great anti-fermentative, anti-corruptive, or preſervative Power upon vegetable Juices *a*); and this without rendering the Liquors unwholeſome, tho' the Fume is diſagreeable, and of itſelf ſuffocative.

6. That the Fumes of burning Sulphur have a Power of diſcharging the Colour of red Wines *a*); and on a like Account theſe Fumes are uſually employed for the Blanching of Silks, Flannels, *&c.*

7. That *Vegetable Curation* depends chiefly upon the Excluſion of the Air and all ſuperfluous Moiſture; and this either ſingly or conjointly *b*)

8. That *Vegetable Curation* conſiſts in keeping all the Principles of a vegetable Subject together undeſtroyed, in their natural Texture or Arrangement *b*).

9. That all ſweet vegetable Juices may be preſerved ſound and ſerviceable, by inſpiſſating them over a ſoft Fire; ſo as to throw off their ſuperfluous aqueous Parts, and leave the ſweet or ſaccharine Subſtance behind, in a ſtate fit for Fermentation, upon the Addition of freſh Water *c*).

10. That ſeveral bitter vegetable Juices, capable of anſwering the End of Hops in Brewing, may be inſpiſſated by the Fire, and preſerved for that Purpoſe *c*).

11. That thoſe extremely corruptible Subſtances, Yeaſt, the Flowers of Wine, and Wine-Lees, may be preſerved ſound, barely by freeing them from their ſuperfluous Moiſture, and ſecuring them from the external Air and too great Heat *d*).

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a) See *Exp* II.
b) *Exp* II, III, IV.
c) See *Exp*. III.
d) *Exp*. IV.

12. That the Buſineſs of *Vegetable Curation* may receive great Improvements by a proper chemical Enquiry, made with a direct View to this Subject; from whence many farther Advantages are derivable to Arts and Trades, particularly to the Sugar-Colonies abroad, to Brewers, Wine-Makers, and Diſtillers in hot Countries; and that the Enquiry likewiſe might be advantageouſly extended to *Animal Curation* *.

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* See *Exp.* IV.

LECTURE XI.

CONTAINING

Ways of illuſtrating and improving the Arts depending upon Vegetable FERMENTATION; *particularly* Brewing, Diſtilling, Vinegar-Making, &c.

The Subject. 1. IN our laſt Lecture we endeavoured to ſhew the Method of procuring certain vegetable Commodities, and preſerving them uncorrupted, for the Service of Arts: In our preſent, we ſhall conſider ſome Uſes of theſe Commodities, when thus preſerved; or the Ways of employing them, ſo as to afford various Preparations for the commodious carrying on of Trade, and the Buſineſs of ordinary Life.

2. As our Conſideration is reſtrained to the vegetable Kingdom, the Arts that will chiefly come before us at preſent are, thoſe of Wines, Sweets, Malt-Liquors, Vinegars, and Brandies; in all which we have already made ſome Progreſs *. But there remains much behind for the Improvement of theſe Arts; which lie in a State far from that Simplicity, on which their Perfection ſeems to depend.

The Deſign of the Experiments. 3. Theſe Arts we ſhall here endeavour to improve by four direct Experiments. The *firſt* is capital, and calculated to ſhew the Method of reducing vegetable Juices, cured by Decoction;

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* See *Lect.* X.

tion or Inſpiſſation *, back to a State fit for affording Vinegars, Wines, and Brandies by Fermentation; and at the ſame Time to exhibit a new Method of making an artificial *Muſt*, or *Stum*, as good as the natural, and equally fit for refermenting, fretting, improving, and making Wines, Vinegars, and Spirits, in all Countries.

4. The *ſecond* Experiment will exhibit the common Methods of forcing, or fining down, fermented vinous Liquors, ſo as to render them expeditiouſly bright or clear, and fit for Uſe.

5. The *third* Experiment will ſhew a Method of converting White Wines into Reds; and of recovering, or improving, the Colour of decayed red Wines.

6. The *fourth*, a Method of concentrating Wines, Vinegars, or Malt-Liquors, for Carriage, or Exportation.

7. The *fifth* will ſhew a Method of recovering prick'd Wines.

8. The *ſixth* and laſt will ſhew a more profitable Method, than that commonly uſed in *England*, of fermenting Malt for Diſtillation, or the Production of common inflammable Spirits.

Theſe Experiments now follow in their Order.

EXPERIMENT I.

To ſhew the Method of reducing vegetable Juices, cured by Inſpiſſation or Decoction, back to a State fit for affording Wines, Vinegars, and Brandies, by Fermentation; and at the ſame Time to exhibit a Method of making an artificial Muſt, or Stum, as good as the natural, and equally fit for refermenting, fretting, improving, or making Wines, Vinegars, and Spirits.

9. We took three Pounds of white Lump Sugar well cleanſed of its Treacle, and melting it *Artificial Muſt prepared.*

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* See *Lect.* X. *Exp.* III.

in three Quarts of fair Water, added in the boiling half an Ounce of finely pulverized *Rheniſh* Tartar; which diſſolved with a remarkable Ebullition, and gave a grateful Acidity to the Liquor. Then taking the Veſſel from the Fire, and ſuffering it to cool, we thus procured a *Muſt*, which in all reſpects reſembled the natural tart and ſweet Juice of a white flavourleſs Grape, when that Juice is well purified, and often racked from its Sediment, in order to make *Stum*. And if our artificial *Muſt* be ſtummed, that is matched, or well fumigated with burning Brimſtone, after the Manner ſhewed in our laſt Lecture *a)*, it thus becomes a perfect *Stum*; which may be made of any Flavour, at the Diſcretion of the Artiſt.

Uſes.

10. This Experiment is ſo pregnant, that it might deſerve to have its Uſes explained by an expreſs Treatiſe *b)*. It affords abundant Inſtruction for improving the Arts of Sweets, Stums, Wines, Vinegars, and Spirits; it likewiſe affords ſome uſeful Inſtructions about the Nature of ſweet and tart vegetable Juices, and the Ways of imitating them by Art. But theſe Particulars we can only juſt touch upon for the preſent.

The Experiment how deduced.

11. The Experiment itſelf was formed upon the Analyſis of the Juice of the Grape before Fermentation; which Juice, to the Senſes, appears no other than a ſaccharine Subſtance diſſolved in Water, with the Addition of a tartarous Acid: And this being fully confirmed by a chemical Reſolution, it was hence eaſy to expect, that if Tartar, which is the natural Salt of Wine, or of any ſweet vegetable Juice fermented, could be artificially diſſolved in a proper Mixture of Sugar and Water, it would give an exact Reſemblance

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a) *Exp.* II.

b See the Appendix to this Lecture.

of the thing. Accordingly it was found upon Trial that Tartar might be thus diſſolved, ſo as to communicate an agreeable Acidity to Sugar, and thus to imitate, in great Perfection, the natural ſweet Juices of Vegetables, without their particular Flavours: and hence our Experiment diſcovers to us the Nature, Uſe, and Perfection of the Art of *Sweets*

A Sweet what. 12. By a *Sweet* is underſtood any vegetable Juice, whether obtained by Means of Sugar, Raiſins, or other Foreign or Domeſtick Fruit, which is added to Wines in order to improve them. Whence we ſee that the Art of Sweet-Making might receive a high Degree of Improvement, by uſing pure Sugar as one general wholeſome Sweet, inſtead of thoſe infinite Mixtures of Honey, Raiſins, Syrups, Treacle, Stum, Cyder, *&c.* wherewith the Sweet-Makers ſupply the Wine-Coopers, to eke out or amend their Wines. For pure Sugar being added to any poor Wine will ferment therewith, improve it, and bring it to a proper Degree of Strength and Vinoſity. If the Wine to be thus amended is tart of itſelf, no Tartar ſhould be added to the Sugar; but if it be luſcious or too ſweet, then the Addition of Tartar is proper.

Extended. 13. The preſent Experiment adds no leſs Improvement to the Art of *Stums*, which may perhaps be hence brought to its Perfection. And here we deſire the Men of Buſineſs would duly reflect, that wherever Sugars go, there go in a ſolid form *Stums*, *Wines*, *Vinegars*, and *Brandies*; that is, the actual Matter out of which, by the bare Addition of Water, theſe ſeveral Commodities may be readily prepared. For it is by no Means neceſſary that Sugars ſhould be imported and exported in a liquid Form, for the making of Stums, Wines, *&c.* becauſe it is ſo eaſy to add the Tartar and Water in any Port they arrive at.

Farther Uſes in the Trade of Wines.

14. Our Experiment alſo points out the Way of perfecting the *Art of Wines*, by reducing the component Matter thereof to a ſmall Bulk, and occaſionally, in any Climate, bringing it back with Water into a Muſt; which Muſt may be tinged of any Colour, or impregnated with any Flavour, ſo as to be fermented into a Wine of any Species or Denomination. Thus if a few Drops of the eſſential Oil of Nutmeg, or Cinnamon, were to be rubbed with a little Sugar into a Kind of *Elæoſaccharum* *, and then mixed with our artificial Muſt, or Stum, the Wine made of it would have a very grateful Odour and Flavour. And ſo if an eſſential Oil were procured from the Lees of any particular Wine, and introduced into our artificial Stum, after the ſame Manner, the artificial Wine would thus have the Odour and Flavour of the natural Wine that afforded the Lees; bating for the Roughneſs, Hardneſs, or Dryneſs given by the Huſk and Stone. For our artificial Muſt has no Flavour or Colour of its own, but readily receives and becomes impregnated with either by Art. And how far this Experiment may be uſeful in teaching a Method of making a rich concentrated Wine, for the extemporaneous Improvement of the poorer Sorts, or for making a ſerviceable Kind of extemporaneous Wine, barely by mixing with Water, we recommend to the Trial of thoſe who have a Talent at this Kind of Experiments.

And Vinegars.

15. The Art of *Vinegar-Making* may alſo poſſibly receive a high Degree of Improvement by Means of the preſent Experiment, as it affords us a Method of diſſolving Tartar in Water, on which the whole Art of Vinegar-making ſeems to

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* See hereafter, *Lect.* XIII. *Exp.* IV.

depend. For there are many phyſical and chemical Reaſons and Experiments, to ſhew that Vinegar is no more than a particular Kind of *fluid Tartar*. And the Art of making Vinegar would then be perfect, when it could readily, or extemporaneouſly, prepare and concentrate the Commodity; ſo as to give it a Kind of ſolid or conſiſtent Form, which ſhould render it durable, bring it into a ſmall Bulk, and leave it fit to be reduced by Water into a fluid Form, for Uſe in all Climates.

16. We plainly ſee that the original component Matter of Vinegar, which is Sugar, lies in a ſmall Bulk, and may be readily converted by Water, Air, and Heat into Vinegar *. Sugar in the Act of *Acetification* ſeems wholly converted into a fluid Tartar; and if the aqueous Liquor be ſeparated from Vinegar, we find the Vinegar is thereby rendered the ſtronger: inſomuch that if Vinegar were to be highly concentrated by Congelation, it would become almoſt ſolid, or a Kind of actual Tartar. Whence the Rule is eaſy, that in order to make an almoſt ſolid Vinegar, we ſhould endeavour to diſſolve Tartar in an aqueous Liquor. Whence, for perfecting the Art of Vinegar-Making, we recommend the diſſolving of Tartar largely with Sugar, or Treacle, and the ſtrongeſt Vinegar, by repeated Imbibitions, Heat, and a proper Management.

In the Diſtillation of Spirits.

17. We proceed to ſhew ſome Uſe of our Experiment in the Art of Diſtillation; which Art likewiſe might poſſibly arrive at Perfection by its Means. It is generally known that a taſteleſs, flavourleſs, yet perfectly vinous and cheap Spirit, is the grand *Deſideratum* in the Art of Diſtilling: Now ſuch a Spirit ſeems eaſily procurable from our Stum, made highly acid by the Addition of

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* See *Lect.* VI. *Exp.* II.

Tartar, and fermented till that Acidity prevails, as it ſoon will do, ſo as to prove a true Vinoſity. And thus a highly vinous, yet flavourleſs Spirit, may be obtained at a very reaſonable Charge, if a Man thoroughly underſtands the Art of Fermentation. And ſuch a Spirit might be readily flavoured and converted into French Brandy, Arrack, or any other Kind of Spirit, that commonly ſells for a much greater Price *a)*.

Farther Uſes.

18. Theſe Particulars, with ſeveral others that might be mentioned, hold of our Experiment in its perfect State: for to reduce ſweet vegetable Juices to a pure white Sugar, without any Participation of Treacle, is an extreamly *perfect Curation*, which coſt much Labour before it was diſcovered. But now the thing is common, we ſeem almoſt to neglect it; at leaſt do not enquire into the farther Uſes of ſo capital a Diſcovery, to the apparent Detriment of the Sugar-Trade, and the Colonies thereon depending.

19. Tho' Curation by bare Decoction, or Inſpiſſation, is of a lower Claſs, yet ſtill it has its Uſes *b)*; for even Treacle is an uſeful Subſtance: But the Rob of Malt, as we ſhewed in our laſt Lecture *b)*, may be employed for the making of Beer, Ale, Vinegar, and Spirit, in all Climates, after the ſame Manner as we here uſe Sugar. And the Perfection of this Curation would be, to reduce all ſuch Robs to an actual Sugar; as with ſkill might be done, we apprehend, to Advantage. Tho' as ſome Countries and Palates prefer Malt-Liquors and Corn-Spirits, to Wines and the fineſt foreign Brandies, this Art of Sugar-Making need not be univerſally extended to Malt and Grain.

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a) See hereafter *Lect.* XII.
b) See *Lect.* X. *Exp.* III.

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20. Many other Uſes are derivable to Arts and natural Philoſophy from our preſent Experiment; but we have only Time to mention one more. We ſee that Stums, Wines, Vinegars, and inflammable Spirits of all Sorts, may be commodiouſly obtained by its Means; we now add, that the original Matter of them all may be reduced to a brown, thick, treacly, or other coloured Subſtance, whether red, yellow, or black, and exported under this diſguiſed Form to any trading Part of the World, for preparing theſe Commodities there. And thus the Country poſſeſſed of Sugar, might advantageouſly ſupply many others with Matter for exerciſing of ſeveral Arts; ſuch as the Production of Wines, Beers, Vinegars, and Brandies. And in the ſame Manner might Families be ſupplied with an artificial Muſt, Stum, or Rob of Grapes, for making any Sort of Wine at home, with much greater Eaſe than they now brew Beer: for the expert Artiſt will eaſily give the proper Flavour and Colour of any Wine *, to this artificial Muſt, or Rob; ſo that there ſhould be nothing more required at home, for the making it into Wine, than to add the Water and the proper Ferment in the Caſk.

EXPERIMENT II.

The common Method of Forcing or Fining down fermented vinous Liquors, ſo as to render them expeditiouſly bright or clear, and fit for Uſe.

21. We took an Ounce of fine Iſing-Glaſs beat with a Hammer into Shreds, and diſſolved it by boiling in a Pint of Water, ſo that it became a ſtiff Gelly when cold. Some of this Gelly we whiſked *Wine fined.*

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*) See above, §. 12. and hereafter *Exp.* III.

up into a Froth, with a little of the Wine intended to be fined; then ſtirred it well among the reſt in the Caſk, and bunged it down tight. By this Means the Wine will uſually become bright in eight or ten Days.

Uſes. 22. This Method is beſt ſuited to white Wines: but for red ones, the Wine-Coopers commonly uſe the Whites of Eggs, beat up to a Froth, and mixed in the ſame Manner with the Wines. And theſe are the common Methods of Forcing at preſent uſed in the Wine-Buſineſs.

Rationale. 23. The phyſical Reaſon of the Experiment is this, that the Bodies here employed as the Forcing are viſcous or glutinous, ſo as to entangle themſelves among the flying Lee, or light Feculencies, that float in the Wine; and thus forming a Maſs ſpecifically heavier than the Wine, ſink thro' the Body thereof, like a Net, carrying down all the Foulneſs they meet with in their Way. But when the Wine is extremely rich, ſo that its ſpecific Gravity proves greater than that of the Maſs compounded of the *Forcing*, as it is called, and the Dregs or Lee, this Maſs riſes upwards, and floats on the Top of the Liquor, in which Caſe alſo the Wine will draw off fine.

Inconveniencies of the Method. 24. The principal Inconvenience of this Method of fining Wines is its Slowneſs, as not having its Effect in leſs than a Week, or ſometimes a Fortnight, according as the Weather proves favourable or unfavourable, cloudy or clear, windy or calm; which appears to be Matter of conſtant Obſervation. But the Wine-Merchant frequently requires a Method that ſhall with Certainty make his Wines fit for taſting in a few Hours. And a Method of this Kind there is, but kept as a valuable Secret in a few Hands. Perhaps it depends upon the prudent Uſe of a tartarized Spirit of Wine and the common Forcing, as Acceſſories, along with *Gypſum*, or calcined Alabaſter, as the Principal; all which are to be well romaged, or ſtirred together in the Wine, for half an Hour, before it is ſuffered to reſt.

Fining not always neceſſary.

25. Let it be here obſerved that all Wines, Malt-Liquors, and Vinegars, which are well made and perfect in their Kind, will grow fine of themſelves barely by ſtanding; ſo that if they do not thus grow fine in a reaſonable Time, it is a Sign they labour under ſome Diſeaſe, that is, are either too aqueous, too acid, too alkaline, tend to Putrefaction, or the like. In all theſe Caſes, which may be properly enough called the *Diſeaſes of Wines*, ſuitable Remedies are required before the Wines will grow fine.

Diſeaſes of Wine how cured.

26. To enquire particularly into the Diſeaſes of fermented Liquors, with their reſpective Cures, is not the preſent Deſign *a*); only we muſt obſerve, that the moſt general Remedy hitherto known for all the Diſeaſes of Wines, is a prudent Uſe of a tartarized Spirit of Wine, which not only enriches, but diſpoſes all ordinary Wines to grow fine. But Wines well prepared from artificial Muſt, in the Method above-mentioned, are ſubject to no Diſeaſes. And even thoſe obtained in the common Way may be effectually ſecured, againſt all Diſeaſes, by Congelation, which takes away their ſuperfluous Water without Prejudice to their vinous Parts *b*).

The Uſe of Milk in Wines.

27. Skimmed Milk likewiſe is a proper Forcing for all white Wines, Arracks, and ſmall Spirits; but improper for red Wines, becauſe it diſcharges their Colour. Thus if a few Quarts of well ſkimmed Milk be put to a Hogſhead of red Wine, it will ſoon precipitate the greateſt Part

a) See the Appendix to this *Lecture*.

b) See below *Exp.* IV.

of the red Colour, and leave the Liquor much paler, or almoſt white. Whence this Experiment ſometimes becomes of Uſe in turning pricked red Wines into Whites, where a ſmall Degree of Acidity is not ſo much perceived. And on this Property of Milk depends that other, of Kin thereto, whereby it whitens Wines that have acquired a brown Colour from the Caſk, or by haſty Boiling before they were fermented: For in theſe Caſes, the Addition of a little ſkimmed Milk will alſo precipitate the brown Colour, and leave the Wines almoſt limpid, or of what they call a *Water Whiteneſs*; which is much coveted abroad in white Wines as well as in Brandies.

EXPERIMENT III.

A Method of converting White Wines into Reds; and of recovering the Colour of decayed red Wines.

White Wine coloured red.

28. We put four Ounces of what is commonly called *Turnſol Rags* into an earthen Veſſel, and poured upon them a Pint of boiling Water; then covering the Veſſel cloſe, and ſuffering it to cool, we ſtrained off the Liquor, which we found of a very deep red Colour, inclining to purple; ſo that a ſmall Proportion thereof would give a beautiful bright red, to a large one of white Wine mixed therewith.

The Experiment improved.

29. For keeping, this Tincture might be mixed with Brandy, or made into a Syrup with Sugar; but the uſual Way with the Wine-Coopers and Vintners is to infuſe the Rags cold in Wine, for a Night or more, and then wring them with their Hands. The Inconvenience of this Method is, that it gives the Wine a diſagreeable Taſte, or what is vulgarly called the *Taſte of the Rag*:

whence the Wines thus coloured uſually paſs among the Judges for *preſſed Wines*, that have got this Taſte from the Canvas Bags in which the Lees were preſſed.

30. The Way of infuſing the Rags in boiling Water is not attended with this Inconvenience; but then it loads the Tincture with Water, which may prove prejudicial to the Wine; or if made into a Syrup, or mixed with Brandy, the Colour is thus diluted, or weakened; ſo that a large Quantity of theſe additional Ingredients comes to be uſed with a ſmall one of the Colour, tho' that alone be the Thing required.

31. Hence the Buſineſs of colouring Wines red is attended with conſiderable Inconveniencies, in thoſe Countries that do not afford the *tinging Grape*, which yields a Blood-red Juice, and with which the Wines of *France* are often ſtained. In Defect thereof at *Oporto* they ſometimes uſe the Juice of Elder-Berries, and ſometimes Logwood, when their Wines are not naturally red enough; for this Colour, it ſeems, they muſt have, to make them ſaleable. *Inconveniencies.*

32. The Colour afforded by our preſent Experiment is not properly the *Port*, but the *Bourdeaux-Red*, which does not ſo well ſuit with *Port-Wines*: Whence the Foreign Coopers are often diſtreſſed for Want of a proper Colouring to their red Wines in bad Years. We would, therefore, recommend to them the Uſe of an Extract made by boiling *Stick Laque* in Water; which gives a rich Red, that comes tolerably cheap, and is, perhaps, the perfect red *Port*-Colour [*]. But if this proves unſatisfactory, let a Method be tried of making a Laque out of the Skins of the ting- *Remedied.*

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[*] See hereafter *Lect.* XIV. *Exp.* II.

ing Grape, or *Raiſin de Teinte*. Cochineal might likewiſe anſwer the Purpoſe, tho' it loſes of its Colour by mixing with all acid Wines. Elder-Berries give this Colour in a tolerable Degree, but not without communicating a nauſeous Flavour.

33. The Produce of our preſent Experiment might anſwer well, if the Colour could be had pure, or made up into Cakes, without being imbibed by Rags; for it is very eaſy to obſcure its too great Brightneſs, or vivid purple Briſkneſs, by the Addition of a little burnt Sugar, Rob of Sloes, Rob of Oak, Rob of Wine, or any other Colour bordering upon the Tawny, ſo as to make a true *Port*-Colour.

EXPERIMENT IV.

A Method of condenſing or concentrating Wines, Vinegars, and Malt-Liquors, for Exportation.

Wines and potable Liquors improved by Freezing.

34. We took a Quart of ordinary red Port-Wine, included in a *Florence* Flaſk, and placing the Flaſk in a Mixture of one Part common Salt and two Parts Snow, or beaten Ice, we found the more aqueous Part of the Wine was ſoon turned to Ice; from which, by a bare Inclination of the Glaſs, the thick, rich, or more vinous Part of the Wine, was eaſily drained.

The Experiment regulated.

35. This Experiment is here performed too quick, ſo that ſome of the thick and valuable Parts of the Wine are catched and detained in the Ice. To perform it in Perfection, the natural freezing Cold ſhould be employed; by which Means, Wines, Vinegars, and Malt-Liquors may

be reduced to a fourth of their ordinary Bulk, without any conſiderable Loſs of their eſſential Parts; little more than the uſeleſs, or detrimental Water being thus ſeparated, ſo as to leave all the eſſential Parts of the Wine admirably cured, or capable of remaining perfect, for ſeveral Years, as has been found upon Trial. And by a prudent Uſe and Application of this Experiment, we conceive that great Improvements might be made in the Wine-Trade.

36. For by a proper Contrivance, and a little Dexterity, which may be eaſily gained by Experience, large Quantities of the pooreſt Wines might be thus, at little Expence, converted into rich ones, ſo as to increaſe their Value in Proportion to the Diminution of their Bulk. And thus alſo, by repeating the Operation, might extremely rich and generous Wines, or a true Quinteſſence, be procured, for the Amendment of the thinner and poorer Sorts. And in this View it ſhould be remembered, that mountainous Wine-Countries are often furniſhed with Snow, by means whereof artificial Freezing might be practiſed in the time of Vintage; the bare intimation of which may give a ſufficient Hint for introducing a new and uſeful Branch of Buſineſs, as Wines may be hence concentrated after Fermentation, no leſs commodiouſly than the Juice of the Grape before that Operation *a*). And if to this be added, that the *Art of Congelation* is alſo capable of Improvement from a proper Uſe of *Sal-Ammoniac* and Water *b*); for, as the *Sal-Ammoniac* remains eaſily recoverable, it ſhould ſeem that little more than a ſuitable Apparatus is required to bring this

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a) See *Lect.* X. *Exp.* III.
b) See *Lect.* V. *Exp.* II.

Buſineſs to Perfection, with all deſirable Advantage.

EXPERIMENT V.

A Method of recovering prick'd Wines.

Prick'd Wine recovered.

37. To a Bottle of prick'd red *Port*-Wine we added about half an Ounce of tartarized Spirit of Wine; then ſhaking the Liquor well together, we ſet it by for a few Days, expecting to find it remarkably altered for the better; as upon Trial it appeared indeed to be.

38. This Experiment depends upon the uſeful Doctrine of *Acids* and *Alkalies* a). All perfect Wines have naturally ſome Acidity; but when this Acidity prevails too much, the Wine is ſaid to be *prick'd*, which is a State thereof tending to Vinegar *b*). But the prudent Introduction of a fine *alkaline Salt*, ſuch as that imbibed by Spirit of Wine digeſted upon Salt of Tartar, (for ſo the tartarized Spirit of Wine is prepared) has a direct Power of taking off the Acidity; to which Effect the Spirit of Wine alſo contributes, and is in other Reſpects a great Preſervative of fermented Liquors *c*). And if the Operation be dextrouſly performed, prick'd Wines may be thus recovered, and made to remain ſound and ſaleable for ſome Time. The ſame Method is likewiſe applicable to *hard* Malt-Liquors, or ſuch as are but juſt turned ſour, and not near becoming Vinegar.

39. An Expedient of the ſame Nature is frequently made uſe of to recover ſour Small-Beer, by

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a) See theſe Terms explained in the *Gloſſary* prefixed to our *Lectures*.

b) See *Lect.* VII. *Exp.* II.

c) See *Lect.* VII. *Exp.* IV. and the Appendix to the preſent *Lecture*.

by adding thereto a little Chalk or Powder of Oyſter-Shells; for Chalk and Oyſter-Shells being terreſtrial Alkalies, immediately take off the too great Acidity of the Liquor, and cauſing an Ebullition therewith, give it a conſiderable Briſkneſs, if drank before the Ebullition is entirely finiſhed. In order to continue it the longer, 'tis beſt to add the Chalk, or Oyſter-Shells, whole to the Liquor in the Caſk; but Care muſt be taken to drink it out ſoon, otherwiſe the Liquor will ſpoil *a)*.

EXPERIMENT VI.

A more profitable Method, than the common, of fermenting Malt for Diſtillation, in order to obtain from it a Brandy, or inflammable Spirit.

40. We took ten Pounds of Malt reduced to a fine Flour, and three Pounds of common Wheat-Meal; to theſe we added, firſt, two Gallons of cold Water, and ſtirred them very well together; then five Gallons of Water boiling hot, and ſtirred all very briſkly again. Letting them now ſtand for two Hours, we repeated the Stirring again, and when the whole was grown cold, we added to it two Ounces of ſolid Yeaſt, and ſet it by in a warmiſh Place, looſely covered, to ferment *a)*. *Brewing for Diſtillation.*

41. This Experiment exhibits the *Dutch* Method of preparing the *Waſh*, as it is called, for Malt-Spirit, whereby they ſave much Trouble, and procure a large Yield of Spirit; thus commodiouſly reducing the two Buſineſſes of Brew-

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a) See *Lect.* VII. *paſſim.*

ing and Fermenting, to a ſingle Operation. In *England* the Method is, to brew and maſh for Spirit juſt as they ordinarily do for Beer; only inſtead of boiling the Wort, they pump it into large Coolers, and afterwards run it into their fermenting Backs, to be there work'd, or fermented with Yeaſt; thus beſtowing twice as much Labour in the Operation, as is required; and at the ſame Time loſing conſiderably of their Quantity of Spirit, by leaving the groſs Bottoms out of the Still, for Fear of burning.

And Advantages. 42. In the Manner of our preſent Experiment, where the Malt is ground fine, we have all its fermentable Parts ſet looſe, ſo as at once to mix with the Water. And we can thus put all the *Bottoms* into the Still, without Danger of burning; becauſe being rendered ſo fine at firſt, they entirely loſe their Clammineſs in the Fermentation, ſo as to become light or buoyant, and thus increaſe the Yield of the Spirit.

Regulation. 43. The Meal of unmalted Corn is found neceſſary to be mixed along with the Malt, to prevent its over-fermenting, and throwing off the Matter of the Spirit. But as Diſpatch is here particularly required, to avoid Expence and a large Apparatus of Veſſels, a conſiderable Quantity of Yeaſt is added to quicken the Fermentation, ſo that it may be finiſhed in two or three Days.

44. More Yeaſt ſhould be added if the Weather be cold, and leſs if it be hot; the Converſe is to be underſtood of Meal, more whereof is required in hot Weather to check, and leſs in cold, to haſten the Operation; which in the preſent Caſe is deſigned to be violent, contrary to what ought to be obſerved in the Fermentation for Wines, where the ſlower the Operation is performed, the better the Liquor will prove. Which

Rule may likewiſe obtain here in a leſs Degree: for it is poſſible to ferment the Waſh ſo violently, that it ſhall ſoon end in Putrefaction a). And thus by rightly conducting the ſeveral Parts of the Proceſs, we may, by Diſtillation, procure all the Spirit that Malt and Meal are capable of affording by Fermentation. The Method of procuring this Spirit will be ſhewn in our next Lecture b).

AXIOMS *and* CANONS.

1. We have ſeen in the preceding Enquiry, that excellent Stums, Sweets, Wines, Vinegars, and Brandies, may be prepared from Sugar, in any Climate, where Water and Tartar can be procured c).

2. That Malt-Liquors, and Malt-Vinegars, may be commodiouſly prepared in any hot Climate, from the *Rob* or Treacle of Malt; which is fit for Tranſportation, ſo as to convey the deſired Virtue of the Malt in a ſmall Bulk, and retain it perfect for ſeveral Years d).

3. That the Perfection of the *Art of Vinegar-Making* depends upon the Converſion of Sugar into a fluid Tartar; or a Method of permanently diſſolving a large Proportion of Tartar in Water e).

4. That it is poſſible to reduce both Wines and Vinegars to a thick Syrupy Form f): ſince the

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a) See *Lect.* VII. *paſſim.*
b) See *Lect.* XII. *Exp.* I.
c) See *Exp.* I. See alſo *Lect* VII. *Exp.* I.
d) *Exp.* I. See alſo *Lect.* X. *Exp.* III.
e) See *Exp.* I. See alſo *Lect.* VII. *Exp.* II.
f) *Exp.* I, IV.

original Matter of them both, *viz.* Sugar, is ſolid, and ſince they both may be concentrated by Froſt to a high Degree of Richneſs and Thickneſs.

5. That a new Art may be introduced of ſupplying Foreign Countries with a proper, or rich, ſyrupy, or treacly Subſtance, which ſhall lie in a ſmall Compaſs, for the making of Wines, Beers, Vinegars, and Spirits, in all Climates, with conſiderable Advantage *a*): A Conſideration deſerving the Attention of the Sugar-Colonies, or their Mother-Kingdoms.

6. That the ſweet and tart Juices, as thoſe of Summer-Fruits, Cherries, Grapes, *&c.* conſiſt of a ſaccharine and tartareous Subſtance; or, to ſpeak explicitly, of an actual Sugar, and an actual fluid Tartar: which affords an uſeful Rule for improving theſe natural Juices in bad Years, and again for imitating them by Art; as alſo for producing Wines, Vinegars, and Brandies, without them, where Sugar and Tartar can be procured *b*).

7. That there is a great Affinity betwixt Sugar and Tartar, ſince they not only reſide together, and are intimately mixed in all ſweet and tart vegetable Juices, but alſo ſeem readily convertible into each other; for the acid and tart immature Juices of Plants become ſaccharine by Ripening; Wine made wholly of Sugar and Water ſhoots a large Quantity of Tartar; and Sugar is wholly convertible into Vinegar, which is a fluid Tartar. Whence much Light might be derived for explaining the Nature of Vegetation, Acidity, Sweetneſs, Immaturity, Ripeneſs, Vi-

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a) *Exp.* I, IV. See alſo *Lect.* X. *Exp.* III.

b) *Exp.* I. See alſo *Lect.* VII. and X. *paſſim.*

nification, Acetification, and the Art of procuring Tartar *a*).

8. That the Improvement, or Perfection, of ſeveral Arts may depend upon a ſingle Experiment; as we remarkably ſee by our ſimple Experiment of diſſolving Tartar in Water and Sugar *b*); which has a direct Tendency to improve the ſeveral Arts of Sweets, Stums, Wines, Vinegars, and Spirits.

9. That a very large Proportion of Water enters the natural Compoſition of Stums, Wines, Vinegars, and Spirits *c*); as plainly appears from hence, that the eſſential Matter of them all is contained in dry Sugar, which being barely diſſolved in Water, and fermented, becomes Wine; or a Liquor that may, by Congelation, be reduced to a fourth, or a ſixth Part of its natural Bulk, without any conſiderable Loſs of its valuable Part, or of little more than its ſuperfluous Phlegm or Water *d*).

10. That the Diſeaſes of Stums, Wines, and Vinegars, are owing to an Over-Proportion of aqueous Parts; ſo that if their Water be taken away, without doing Violence to the eſſential Matter, thoſe ſeveral Commodities may be preſerved in a State of Perfection; as we ſee they actually are by Concentration, or Congelation, which thus advantageouſly ſeparates their aqueous Parts without hurting the reſt *d*).

11. That numberleſs new Sorts of Wines and Brandies are producible, barely by adding any well-ſcented Vegetables, or their eſſential Oils, or a

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a) See *Lect.* VII. and X. See alſo the preſent *Lecture*, *Exp.* I.

b) *Exp.* I.

c) *Exp.* I. and IV.

d) See *Exp.* IV.

Mixture of ſuch Oils, to a natural or artificial Muſt in the Fermentation *a*). And the ſame may be proportionably underſtood of the Colours of Wines; which might, by proper tinging Ingredients, be thus procured blue, green, yellow, or of other Colours, if it were neceſſary, as well as pale, or red *b*).

12. That the phyſical Agent in the Fining of Wines, and other fermented Liquors, is ſome proper viſcous Subſtance, which entangles the groſs Particles, and either ſinks with them to the Bottom, or riſes to the Top, ſo as to ſeparate and keep them ſeparate from the Body of the Liquor; and that, on this Foundation, better Methods of fining may be diſcovered, than thoſe hitherto commonly known and practiſed *c*).

13. That *tartarized Spirit of Wine* is a Remedy for acid Wines, and not only abates their Acidity, but alſo ſtrengthens, and diſpoſes them to grow fine, when they are thick and turbid *d*).

14. That Milk, deprived of its Cream, will diſcharge the Colour of red Wine, by precipitating the tinging Matter to the Bottom; and ſo likewiſe leſſen, and take off the brown Colour, wherewith white Wines are ſometimes accidentally tinged *e*).

15. That the Buſineſs of colouring red Wines artificially may be improved by a proper Uſe of an artificial Turnſol without Rags; ſuch as an Extract of Stick-Laque, *&c.* but particularly an artificial Tincture of the Huſk or Skin of the red Grape, or a particular Laque made from the *Raiſin de Teinte f*).

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a) *Exp.* I. See alſo *Lect.* VII. *Exp.* I.
b) See *Exp.* III.
c) *Exp.* II.
d) *Exp.* V. See alſo the Appendix below.
e) *Exp.* II. *f*) *Exp.* III.

16. That it is in the Power of Art greatly to accelerate the Operation of vinous Fermentation, ſo as to finiſh the whole in a few Days Time: But that this ſhould be done only when a Spirit, and not a Wine, is intended; becauſe ſuch a haſty Fermentation ſubverts or deſtroys the Texture requiſite in vinous Liquors *a*).

APPENDIX to LECTURE XI.

SECT. I.

The Theory of Vinous Fermentation.

1. The extenſive Doctrine of Vinous Fermentation being little regarded, in Proportion to its philoſophical and practical Uſes, it may be proper in this Place to lay down its *Theory*, after a conciſe axiomatical Manner (as we are the better enabled to do from the Labour which Dr. *Stahl* has beſtowed upon this Subject *b*) and ſubjoin a few Obſervations with regard to Practice.

2. *Vinous Fermentation* is an inteſtine Motion performed by the inſtrumental Efficacy of Water; ſo as to ſtrike aſunder, attenuate, tranſpoſe, and again collect and recompoſe, in a particular Manner, the Salt, Oil, and Earth of a fermentable Subject *c*).

3. Fermentable Subjects, therefore, are mixed Bodies; conſiſting of *Salt*, *Oil*, and a *Subtile Earth* *d*).

4. Theſe compound Particles of all fermentable Subjects are ſo ſmall, that when aſunder they become imperceptible to the Senſes; for

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a) See Lect. VII. *paſſim*. See alſo the preſent, *Exp.* VI. and the following *Appendix*.

b) See his *Zymotechnia fundamentalis*.

c) Conſider all the *Inſtances*, or what ſeems equipollent to them all, Sugar and Water.

d) Into which all fermentable Subſtances are reſolved by a chemical Analyſis.

neither the Touch nor the Sight diſtinguiſhes them: Whence being mixed with an aqueous Fluid, they leave it tranſparent. Neither have fermentable Bodies any conſiderable Smell or Taſte, beſides the Taſte of Sweetneſs.

5. Theſe *Principles* of Fermentation, *viz.* the Salt, Oil, and Earth, muſt of Neceſſity be in a compound State; for Separation preſuppoſes Connexion *a*). And by Compoſition is not here underſtood bare Juxta-poſition, but a very intimate Coheſion of the ſmall and different Particles: So that the Salt, Oil, and Earth, in each of theſe little and inſenſible Compounds, are in actual Coheſion, Connexion, and Union.

6. When, therefore, any one of theſe *Principles* abounds in an Over-Proportion for an intimate Union, the whole Efficacy of the Fermentation is either ſtopped and impaired, or elſe preſently determined. and limited to one certain Species.

7. And this is to be particularly remarked of the volatile or eſſential *Oil*; which being in an Over-Proportion for an intimate Union with the reſt, rather hinders than promotes vinous Fermentation, but greatly diſpoſes the Subject to Putrefaction *b*).

8. But if the *Salt* predominates, this does not ſo much prevent the Succeſs of the Fermentation, provided it be in ſome Kind of Connexion with the oily and earthy *Principles*: And if it be not thus connected, it is readily taken, by Solution in the Water, from the other duly mixed Portion, and thus, in ſome Meaſure, promotes and aſſiſts the Operation.

9. This equable Connexion of Salt, Oil, and Earth into a ſingle compound Particle, makes a

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a) See above §. 2.

b) As in Mace, Cloves, Nutmeg, *&c.*

Corpuſcle ſoluble in Water; that is, this compound Corpuſcle is, by Means of its ſaline Particle, connected with the aqueous Corpuſcles, and moved up and down therewith; that is, it becomes diſſolved therein.

10. Where theſe compound Corpuſcles are not thus connected with the Water, many of them join together either into a groſs Matter *a*), or into a looſe, chaffy, or ſpungy one *b*).

11. When diluted with a little Moiſture, theſe compound Corpuſcles feel ſlippery, clammy, and unctuous to the Touch, and after the like Manner affect the Taſte with a ropy Sweetneſs or Inſipidity *c*).

12. When undiſturbed, and left to themſelves, they preſerve their mutual Coheſion, and their ſolid or dry Conſiſtence, without Alteration *d*).

13. But as ſoon as an aqueous Fluid is put to them, there preſently begins a Commotion, and afterwards a ſubtile Separation among them.

14. This Commotion and Separation firſt begins in the whole Subſtance *e*): for before Water is added, the Subject may remain in dry, ſolid, and large Pieces *f*); which being reduced to Powder, each Grain thereof is an Aggregate of many leſſer compound Corpuſcles; and theſe being put into Water, diſſolve and ſeparately float therein, till at Length they become ſo ſmall as to be inviſible, and thicken the Conſiſtence of the Liquor.

15. When the compound Particles are thus ſeparated from one another, they are next gradually

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a) As in the Lees of Wine.
b) As the Grains in Brewing.
c) As appears in all Inſtances.
d) Conſider Malt, Raiſins, Sugar, and all the Inſtances.
e) As when Sugar diſſolves in Water.
f) As in Malt, Sugar, *&c.*

dually ſeparated from their own different Parts, that is, the different Particles whereof they conſiſt, *viz.* the Salt the Oil, and the Earth, are diſjoined from one another by the Interpoſition of the Particles of Water.

16. The firſt Commotion is no more than a bare Solution, when the Water lays hold of the ſaline Parts of the compound Corpuſcle, and thus carries them about with itſelf. For of theſe ſeveral *Principles* the ſaline one ſooneſt diſſolves in Water.

17. But the ſucceeding Separation, *viz.* the *fermentative Motion*, is a different Thing, and what diſentangles the oily and earthy Parts from the ſaline, partly by the Impulſe of the others in their Motion, and partly by the Force of the aqueous Particles that are now continually meeting and daſhing againſt them.

18. This Motion is performed by the Water, as a Fluid, or Aggregate of an infinite Number of Particles, in actual and perpetual Motion; their Smallneſs being proportionable to that of the fermenting Corpuſcles, and their Motion, or conſtant Suſceptibility of Motion, by Warmth and the Motion of the Air, diſpoſing them to move other ſubtile, moveable Corpuſcles alſo.

19. But more particularly, an aqueous Fluid gives this Commotion, by the certain Agreement of Figure and Size which its Particles have with thoſe of the *Salt* of the fermentable Subject: Whence they come to be readily and cloſely applied together, ſo as to move almoſt like one and the ſame compound Corpuſcle; whilſt the Water is no way diſpoſed to cohere immediately with the Oil or Earth. And thus an unequal Concuſſion is made in the compound Corpuſcles of the Subject; which Concuſſion at

length ſtriking out the ſaline Particle, and looſening the others, brings on a Separation of the original Connexion of the Subject.

20. Thus if, inſtead of Water, an oily Fluid were poured upon any fermentable Subject, no vinous Fermentation would enſue; as the Oil can neither give a ſufficient Impulſe to the compound Corpuſcles, which are groſſer than its own conſtituent Particles, nor force away the oily or ſaline Particles of the Subject from the Connexion of the others, which detain, and as it were envelope or defend them, from its Action.

21. Hence an *aqueous Fluid* alone is the true *Inſtrument* for procuring a fermentable Motion to theſe mixed Corpuſcles of the Subject.

22. As the ſmall Parts of this aqueous Fluid are in a perpetual Motion, and by Means thereof affect the compound Corpuſcles of the Subject, a certain Degree of this Motion is required, which principally depends upon external Heat.

23. It is true, a conſiderable Degree of cold will not abſolutely prevent all Fermentation, though it will greatly retard it; and a boiling Heat will prevent it ſtill more. The due Heat therefore for promoting and quickening the Operation, is a tepid one, or the mean betwixt the two Extremes of Freezing and Boiling.

24. The Admiſſion of the Air alſo, though not of abſolute neceſſity, yet greatly promotes and quickens the Action, as being a capital *Inſtrument* in the Moving of oily Particles, and the true Analyſer of oily Subjects, in Concurrence with the Motion of Fire *.

25. But whilſt the Air thus contributes to haſten the Effect, it at the ſame Time, by its

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* See *Lect.* II. *Exp.* III. IV.

Activity, cauſes ſome remarkable Alterations in the oily Part; as being capable not only of moving, but of abſolutely diſſolving and diſplacing it from its original Connexion, and thus carrying it off with itſelf from the whole Maſs *a*).

26. And hence, though the Conſideration of the Air does not in the general ſo properly belong to Fermentation, yet it does in particular; as having an accidental Power to alter every Species of this Operation: Whence its Agency ought to be well underſtood, in order either to procure deſireable Alterations in the fermenting Maſs, or to prevent and correct ſuch as are not eligible.

27. The *oily Principle*, which the Air thus ſeparates and diſſolves, is alſo elaſtic, though it probably has that Property from its Intercourſe with the Air itſelf, added to an extreme Subtility of Parts; ſo that a ſmall Bulk thereof containing a large Number of individual Particles, may fill and ſatiate a large Bulk of Air *b*).

28. To proceed: When an *aqueous Fluid* is added to a fermentable Subject, expoſed to a temperate Heat, and in ſome ſmall Degree to the open Air, a fermentative Struggle immediately ariſes; the Water by its continual inteſtine Motion diſſolving the ſaline Part of the compound Particles, and carrying them up and down with itſelf infinite Ways, amidſt innumerable other Particles, as well merely aqueous as fermentable ones: Whence, by this Colliſion and Attrition, the oily and earthy Particles are at length ſepa-

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a) As may appear by the Loſs of Spirit and Flavour in open Fermentation, where the Matter is expoſed to too much Air.

b) As in the Atmoſpheres of odoriferous Vegetables; and again in Perfumes or ſtrong-ſcented Drugs; as Muſk, Ambergreaſe, Camphire, Aſſa-fœtida, &c.

rated and disjoined from their Connexion with the ſaline.

29. The oily Particles, as being the moſt ſubtile, and moſt diſpoſed for *elaſtic Motion*, would thus be thrown up to the Surface of the Liquor, and carried off by the Air, if they were not long involved or enveloped in the earthy ones; which are not only undiſpoſed and unfit for Avolation, but alſo ſtrongly inclined to form larger Collections or Aggregations with other earthy ones, and ſo ſink with them to the Bottom *a*).

30. But before this can be fully brought about, that is, before many of the earthy Particles are gradually collected together by their frequent Occurſions, ſo as to form a Bulk that can be no longer moved about by the aqueous Fluid, it happens that, by theſe repeated Colliſions, ſome of the oily Particles (now disjoined from the ſaline ones, which are ſtrongly agitated by the aqueous Particles, and ſeparated from the earthy ones) are again, by Degrees, more intimately connected with the ſaline ones; whilſt, on the other Hand, theſe ſame ſaline Particles imbibe and take to themſelves ſome of the earthy ones, which being left ſingle, upon their Separation from the oily Particles, floated ſeparately about in the Fluid *b*).

31. And hence proceed the ſeveral different Conſequences of Fermentation; *viz.* (1) From the Extrication of the ſaline Particles of the Subject proceeds the tart, ſaline, or acid Taſte of

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a) In the Form of Lees or Sediment.

b) Obſerve that this whole Doctrine is not delivered as hypothetical, but as derived from a careful Conſideration of all the *Inſtances*, both *à priori* and *à poſteriori*, in the Way of a juſt *Induction*.

the Liquor; which is more ſenſible at firſt, before the Liquor is duly compoſed and ſettled, or the new Arrangement and Connexion of the ſaline Particles with thoſe of the oily and earthy Kinds compleated: After which the Liquor proves milder, ſofter, or leſs pungent. (2) From the oily Particles being ſet at Liberty, proceeds the ſtrong Smell of the Liquor, and the Head or the ſhining Skin upon the Surface. (3) The earthy Particles collecting together in Cluſters, cauſe the Fluid firſt to appear turbid, and afterwards to precipitate a viſible earthy or clay-like Matter: And ſome of theſe earthy Parts in their Motion arriving at the Head or oily Skin on the Surface, cauſe it to thicken; and afterwards carrying it down along with them, thus conſtitute the *Lees* which abound in Oil. (4) From this Struggle or Colliſion, which is productive both of Solution and a new Connexion in the ſaline and earthy Corpuſcles, proceeds the *Ebullition* in Fermentation. And laſtly, by the ſame repeated Colliſion of the oily with the aqueous and ſaline Particles, the *inflammable Spirit* is produced *a*).

32. *Water* performs this whole Series of Changes, by becoming the Inſtrument and *Medium* of new Separations, Tranſpoſitions, and Combinations; as alſo preſerving theſe new Combinations after they are made, by a Kind of conſtant Interpoſition, or eſſential Concurrence *b*). For Wine cannot, without extreme Alteration, be deprived of all its Humidity; though it may be freed from the ſuperfluous Part thereof by Congelation, without the leaſt Prejudice *c*).

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a) See *Lect.* VII. *Exp.* IV.

b) See *Lect.* XI. *Exp.* IV.

c) This appears to be true in Fact.

33. And although the aqueous Humidity were intirely taken away, yet the fermented Matters would ſtill retain and reſpectively ſhew the Alteration brought upon them; for the Spirit, with its eſſential Aquoſity, would appear in one Place, the acid Salt in another, and the dry Earth, or unctuous *Fæces*, in a third *a*): And in the two laſt the aqueous Part may be totally ſeparated, without any way altering the Places or State they were put into by the Act of Fermentation *b*).

SECT. II.

Practical Obſervations relating to vinous Fermentation.

1. According to the Doctrine above delivered, every fermentable Subject is in itſelf, or may be reduced to, a dry and ſolid Body, conſiſting of oily, ſaline, and earthy Parts, ſo put together as perfectly to diſſolve with Water into a tranſparent clammy Liquor: Whence Malt or other Grain, Grapes or other Fruit, are to have their proper fermentable Parts eſtimated by the Quantity of dry, pure, fermentable Matter, or Sugar, they would yield; all their other Parts being either chaffy or aqueous, and foreign to the real Purpoſe of Fermentation.

2. This teaches us a Rule for reducing all fermentable Matters to their leaſt Dimenſions, and preſerving them at all Times fit and perfect for Uſe; *viz.* by making them into pure dry *Sugars:* Which, though at preſent generally

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a) As we ſee in Tartar, and dry Wine Lees.

b) See *Lect.* VII. *paſſim.*

practiſed upon the Sugar-Cane only, is performable to good Advantage upon other Subjects *a*).

3. The Perfection of Fermentation in general depends upon three Things; *viz.* (1.) the Goodneſs and Suitableneſs of the Subject; (2.) the Goodneſs and Proportion of the Water put to it; and (3.) the Regulation of the Operation.

4. The Goodneſs of the Subject in general is determined by its Purity and perfect Solubility in Water, without impairing the Tranſparency thereof, or changing its Colour. And this Character is excellently anſwered by the fineſt Sugar; though the uſual Manner of preparing and refining it, by a ſtrong Heat, ſomewhat indiſpoſes it for a ready Fermentation, which newly expreſſed and unboiled vegetable Juices are greatly diſpoſed to; whence their Fermentation is much ſooner finiſhed.

5. That Water is generally allowed beſt for Fermentation, which of itſelf contains moſt fermentable Parts; and ſuch is, (1.) the Water that naturally grows along with Fruits; (2.) Rain Water, which is impregnated with vegetable Matters; and (3.) River-Water, which alſo contains ſome vegetable Subſtances; but (4.) Spring Water is the pureſt and leaſt altered by foreign Mixture: Whence the trueſt Eſtimate may be made of a fermentable Subject by its Means, provided it have no Peculiarity contrary to the Nature of Fermentation *b*).

6. The Quantity or Proportion of the Water is limited by the Nature of the Thing. We ſee that dry fermentable Subjects will never of themſelves fall into Fermentation; too little Moiſture

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a) See *Lect.* VII. *Exp.* I. and *Lect.* X. *Exp.* III.

b) See *Lect.* V. VII. and X.

diſpoſes them rather to putrify than ferment * ; and too large a Proportion ſcatters and diffuſes them, ſo that the Parts have not their Effect upon each other, and become in a Manner loſt : So that there is a certain middle Proportion which is beſt, and ſuffers the Whole to ferment freely, and to obtain ſuch a Body and Conſiſtence as will enable it to keep ſound and perfect ; and this Proportion is about two thirds or three fourths of Water to one of perfectly pure and dry fermentable Matter.

7. The Regulation of the Operation includes, (1) the Manner of putting the Subject to work ; and (2) the external Regimen during the Operation. The Subject may be ſet to work either with or without Addition, and with or without Heating ; and this according to the Climate or Seaſon of the Year. The recent expreſſed Juice of Grapes ſeldom requires either ; but falls immediately to ferment of itſelf, and finiſhes the Work in a few Days. But in cold Countries all fermentable Juices require to be quickened by artificial Warmth, and the Addition of a proper Ferment. The Heat ſhould be barely tepid, and the Quantity of Ferment moderate ; ſo as to begin the Operation ſpeedily, before the Liquor receives any Damage from the external Air, or Change of Weather. The Ferment employed muſt be of the ſame Nature with the Liquor, or yielded by a fermenting Subſtance of the ſame Kind ; otherwiſe it will introduce and impreſs its own foreign Nature upon the Subject.

8. *Ferments* are thoſe Subſtances which added to a Liquor prepared for Fermentation, make it begin and end the Operation ſooner than it would have done by itſelf. They conſiſt of

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* See *Lect.* VII.

the moſt ſubtile, moveable Parts of the fermenting Liquor, already ſeparated from the groſſer or more ſluggiſh; and are therefore thrown up to the Top of a fermenting Liquor: Whence being taken in their State of fermenting Motion, and added to a freſh Parcel of prepared Liquor, no wonder if they ſoon ſet it alſo in a fermenting Motion. But Care muſt be had not to uſe an Over-Proportion, leſt inſtead of quickening the Operation, it ſhould be perverted by too great a Confuſion and Diſorder; which if it ſhould happen, can not eaſily be ſtopped, nor its Inconveniences be eaſily remedied.

9. The external Regimen during the Operation regards the Admiſſion or Excluſion of the Air, and the Warmth of the Place. The free Admiſſion of the Air greatly promotes and quickens the Operation, but carries away ſome of the fine, volatile, unctuous Parts of the Subject, and conſequently impoveriſhes the Liquor: whence the moſt perfect Way is to exclude the Air, and to perform the Operation in a cloſe Caſk, if Expedition be not required. In this Caſe, a little Space ſhould be left unpoſſeſſed by the Liquor at the Top of the Veſſel, and then there will be no Danger of burſting it. Indeed this might otherwiſe be readily prevented, by the Uſe of a *Valve* to let out the foul Air, which is conſtantly generated in Fermentation, and if too long detained in the Caſk, is apt to be imbibed again by the Liquor, ſo as to give it a nauſeous Taſte and Odour. And if the Climate or Seaſon be cold, the Place of the Operation ſhould be kept moderately warm by Fire, or ſome proper Contrivance; otherwiſe the Fermentation may languiſh, or be checked, before the full Effect is procured.

10. Theſe Cautions being duly obſerved,

the Operation will be performed to great Advantage. When it is fully ended, or rather a little before, the containing Veſſel muſt be cloſe ſtopped up, and kept well ſecured from the external Air, that the Liquor may, of itſelf, grow perfectly bright and fine; as it will do, if no Error has happened in the Management. And this is the moſt perfect Method of fermenting Wines, where the fermentable Liquor is prepared by Art *a*); but other Cautions and Rules are required, when Nature affords the Juice imperfect, or unduly mixed, as in bad Vintages, *&c.* *b*).

11. But this Method of fermenting cloſe is ſomewhat ſlow; and greater Expedition is often required in Practice, inſomuch as ſometimes to become the primary Conſideration. We ſhall therefore next take a View of the ſeveral artificial Means to be uſed for ſhortening the Operation, without any conſiderable Prejudice to the Liquor.

12. The Things that have a principal Tendency to haſten the Buſineſs of Fermentation, are, (1) the making of the Liquor ſufficiently dilute; (2) the Addition of a large Proportion of Ferment; (3) the keeping the Whole in a due Degree of Warmth; and (4) the free Admiſſion of the external Air.

13. 'Tis a common Obſervation, that thin Wines finiſh their Fermentation ſooner than ſuch as are rich; as if, for the Sake of Diſpatch, they ſhould be made a little thinner than uſual. The Defect may be afterwards ſupplied with Spirit of Wine, and richer Wine, according to the Practice in Wine-Countries when the Vintage proves poor and watery *c*).

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a) See *Lect.* VII. *Exp.* I. & *Lect.* XI. *Exp.* I.

b) See *Lect.* VII. & XI. *paſſim.* *c*) See *Lect.* XI. *Exp.* IV.

14. A large Proportion of Ferment has a great Power to forward the Operation, and becomes neceſſary in making all the artificial Wines, where the vegetable Juice is not recent, or where it has felt the Force of the Fire; unleſs the Wine be purpoſely deſigned to ferment imperfectly, that it may retain its Sweetneſs, and appear the richer: but this is always with a Loſs of Strength or Spirit, which, however, may readily be ſupplied by the Help of Brandy.

14. Where the utmoſt Expedition is required, a due Temperature, or tepid Degree of external Warmth, muſt, by all Means, be kept up by Art, if the Climate or Country does not naturally afford it: For Heat has a peculiar Power of liquifying and thinning all Fermentable Juices, ſo as to make them work, without leſſening their Strength as diluting does; which indeed it rather increaſes, if it be not too violent, or too long continued.

16. We have already obſerved, that too free an Admiſſion of the external Air, though it greatly forwards the Operation, yet conſiderably prejudices the Liquor, by carrying off its finer and more ſpirituous Part. The free Air, therefore, is to be admitted prudently, and principally at firſt, in order to excite the fermentative Motion; and this ſpirituous Part may be afterwards detained, or kept from flying off, towards the End of the Operation, by covering the Veſſel cloſe, or giving it but little Vent. And when theſe ſeveral Means are prudently uſed together, the Operation may be performed with conſiderable Expedition and Advantage; provided the original fermentable Matter be rightly diſpoſed, or duly mixed of ſaline or acid, oily, and terreſtrial Parts.

17. The *Phænomena* of vinous Fermentation are various, and differ according to the Degree

of the Operation; though the ultimate Effect is generally the ſame. Sometimes the Fermentation gives manifeſt Signs of itſelf; as by Frothing, Hiſſing, Exploſion, *&c.* and ſometimes again ſcarce any manifeſt Signs at all; whence we may conſider it as an *apparent* or *latent Operation.* The apparent is ſufficiently known by its Signs; but the latent has been leſs regarded.

18. When any fermentable Matter is ſufficiently diluted with Water, it has immediately a natural Tendency to Fermentation, and hath often actually fermented and produced a Wine, though a Spectator could neither ſee, nor well ſuſpect, any fermenting Motion in the Liquor. In this Caſe, where no Ferment has been uſed, and the Operation proceeds in its own natural, ſlow, and ſilent Manner, there may be commonly ſeen on the Surface a thin, ſhining Skin; which, inſtead of a large, frothy Head in the ſtronger Fermentation, keeps in the fine Parts, and prevents their Avolation and Eſcape. Sometimes alſo a Degree of Hoarineſs, Finew, or Mouldineſs, will appear on the Top, without mixing itſelf with the Body of the Liquor, or without communicating any ill Taſte thereto. And in this Manner a ſlow and ſilent Fermentation has been carried on for ſeveral Months, without any ſpirting up of Bubbles, or other common Signs of the Operation; though it has, at laſt, finiſhed its Courſe to greater Perfection.

19. And ſomething like this *ſilent Fermentation* remains for a long Time in the Liquor, after the common *tumultuary Fermentation* is finiſhed, which indeed leaves its Work but imperfect; ſo that the Liquor afterwards requires a conſiderable Time to grow fine, ripen, and become fit for Drinking: Whereas in the ſilent Me-

thod, theſe Ends are all at once carrying on at the Time of the Operation. And here lies a great Part of the Advantage which the ſlow Way of fermenting cloſe has over the common one.

20. It is obſervable, that though a ſmall Quantity of Liquor finiſhes its Fermentation ſooner than a large one, yet the larger proves the better; as a great Body of Liquor is not ſo liable to receive pernicious Alterations, from Heat, Cold, the Air, or other accidental Things. And even where nothing remarkable of this Kind has happened, it is ſurprizing to note the Difference betwixt a ſmall Quantity and a large one, of the very ſame Liquor, fermented in the very ſame Manner, only the one in a ſmall and the other in a large Veſſel.

21. Small Wines may be brought to undergo a ſecond Fermentation, by being mixed with proper fermentable Materials; and thus may be rendered ſtronger and richer, ſo as to be fit for Exportation, *&c.* Otherwiſe it is obſerved that Wines which finiſh their Fermentation in eight or ten Days, will not ordinarily endure the Sea.

22. It is a neceſſary Caution in all Fermentation, to prevent too great external Heat, for Fear of changing the Fermentation to Putrefaction *, and to remove the Wines to a cooler Place, when the Violence of the Operation is over; that they may purge and fine themſelves by Degrees, without Danger of turning acid, as they are apt to do in a hot Place. Or if they cannot be kept cool, they ought to be early racked from their Lees; which tends to preſerve them ſound, and prevents their turning eager, ropy, and foul *a).*

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*) See *Lect.* VII.

23. It is to be obſerved of all Liquors prepared by Fermentation, that the Interpoſition of *Water* keeps not only the ſaline, oily, and ſpirituous Parts, but alſo the mucilaginous and earthy ones, in their due Arrangement and ſome Degree of Connexion; from which if they are again diſturbed, there happens ſuch a Change as cannot well be prevented from proving pernicious, but the Liquor will ſucceſſively and haſtily proceed on to Corruption *a*). Thus if a fermented Liquor be agitated by a great boiling Heat, its proper Arrangement is thereby diſordered, and the Liquor not only becomes manifeſtly thick and turbid, but more ſaline and auſtere, through the Separation of the ſpirituous and oily Particles from the ſaline ones, wherewith, being before in ſome Meaſure connected, their Acrimony was ſheathed or abated.

24. Such Liquors tend ſo much the faſter to Alteration or Putrefaction, if they are not carefully looked after and preſerved; but eſpecially if, through any great Commotion by Heat, the more intimate Connexion of the ſpirituous Parts with the ſaline and mucilaginous, or even with the remaining aqueous ones, be diſturbed and broken: Whence either the whole Maſs turns to Vinegar, or to a ropy, corrupt, putrid Subſtance *a*). But if ſuch fermented Liquors are carefully preſerved at Reſt, and kept from Injuries, they will long remain in a ſound and uncorrupted State; as we continually ſee in Wines and Malt-Liquors.

25. And farther, all theſe fermented Liquors will be fitted to reſiſt the Alterations of the Weather or

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a) See *Lect.* VII.

Seaſons of the Year, with reſpect to Heat, Cold, and a fermenting Humidity in the Air, (which is by ſome eſteemed the Cauſe of Fretting in Wines) if their ſuperfluous Water be artificially ſeparated from them, ſo as that the Liquor itſelf may be concentrated; in which State it will remain for many Years unchangeable, through the Summer's Heat, and the Winter's Cold *.

26. When a chemical Analyſis is made of theſe Liquors, the firſt Part that riſes is *inflammable Spirit*; the next, *Phlegm*, mixed with an Acid, and an eſſential Oil, leaving a thick Matter, or Rob of Wine, at the Bottom; which, when freed from its ſuperfluous Moiſture, is obſerved to be very durable, and full of Tartar. But the bare Mixing of theſe ſeveral Parts together will not make the original Liquor again: Which ſhews that they were all before connected in a certain particular Manner, which was diſſolved and deſtroyed in the Act of Separation; and again, that each of theſe Productions received a particular new Kind of Alteration from that Act of Separation, which will not ſuffer them to reunite as before, without ſome proper intermediate Subſtance, or a new Fermentation.

27. Hence pure Wine conſiſts of much Water, a moderate Quantity of inflammable Spirit, a little eſſential Oil, a Proportion of acid Salt, and a certain mixed Subſtance, or *Rob*, called by *Becher*, the *media Subſtantia Vini*. And whilſt theſe ſeveral Parts remain firmly united together in their due Proportion, the Wine is in its perfect State: But as their Connexion proves looſe, or any one of them becomes deficient, or abounds in an Over-Proportion, then the Wine is faulty,

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* See *Lect.* XI. *Exp.* IV.

and expoſed to Injuries and Alterations for the worſe: And this ſhews us the true Foundation of what may be called the *Health* or *Diſeaſes* of *Wines*.

28. That a large Proportion of Water neceſſarily enters the Compoſition of Wine, appears plainly by its artificial Preparation *a*); and again from the Congelation of the natural *b*). But though this large Quantity of Water is requiſite in the Fermentation, and ſerves to carry it on the better; yet it is not afterwards eſſential to the Wine, but rather foreign and detrimental, expoſing and ſubjecting it to Changes, which it would not otherwiſe undergo: Whence the ſovereign Remedy for all Wines, is to deprive them of their ſuperfluous Water, in order to render them perfect and unchangeable, without ſome uncommon and extraordinary Violence or Accident. And indeed this Remedy is ſo effectual as to make all others unneceſſary; inſomuch that the pooreſt and thinneſt Wines may, by its Means, be rendered perfectly durable, and full bodied *b*).

29. But as there may be ſome Difficulty in the particular Uſe of this grand Remedy (in the large Way of Buſineſs) the next Expedient is, to uſe highly rectified and pure Spirit of Wine, in ſuch Proportion as to prevent all Change for the worſe, and preſerve the eſſential Parts of the Wine, as it were by a Balſam. But when the Caſe is very bad, this Remedy of itſelf will ſcarce prove ſufficient, unleſs aſſiſted by ſomewhat to give a Body as that gives Strength. Whence it is highly convenient to have always at Hand a

a) See *Lect.* VII. *Exp.* I.

b) See *Lect.* XI. *Exp.* IV.

Quantity of Wine made as rich as ever it will ferment; a ſuitable Proportion whereof being added along with the Spirit, will have a very good Effect; eſpecially if the Whole be quickened with a little *eſſential Oil of Wine*, which, in the Caſe of over-aqueous Wines, is generally deficient. And this being a capital Diſeaſe in Wines, or that to which moſt of the reſt are originally owing, it may be proper here to give a Form of a Remedy which has been found effectual for the Purpoſe.

30. Take an Ounce of fine eſſential Oil of Wine, mix and grind it with a Pound of dry Loaf-Sugar into an *Elæoſaccharum*; diſſolve this *Elæoſaccharum* in two Gallons of the richeſt Wine; and add to it two Gallons of the fineſt Spirit of Wine, ſo as that they may be well incorporated together. The Doſe of this Mixture muſt be proportioned to the Exigence; but in ordinary Caſes one half will ſuffice for a Pipe of Wine.

31. There is a Diſeaſe of Wines oppoſite to the former, and that is when too much of their aqueous Moiſture is drawn from them, whence they become dry and parched, as it were, for Want of it. This Caſe indeed cannot well happen, except by the Method of Condenſation; whereby Wines may have their eſſential Parts brought ſo cloſe together, as to become unfit for Drinking till ſet more aſunder, and diluted. But this muſt not be attempted with Water alone, for Fear of inducing a Flatneſs. The beſt Way is, to have a dilute or thin taſteleſs Wine ready at Hand for

the Purpoſe *a*); whereby any Degree of Smallneſs may be given at Pleaſure.

32. But the artificial Method of preparing Wines renders all Remedies unneceſſary, as it intirely prevents their Diſeaſes; ſo that they need not be made either too aqueous, or too dry, but conſtantly of a perfect full Body, and therefore not ſubject either to Acidity, Ropineſs, or Foulneſs, when once well cleared of their groſs Lees, in the ordinary Way of Racking.

33. But in Caſe the Wine ſhould not ſoon grow fine of itſelf, the Addition of a little tartarized Spirit of Wine will haſten the Effect *b*): Or, to make at once a general Remedy for Wines that are too poor and aqueous, or will not thoroughly fine themſelves; let a pure, taſteleſs, and totally inflammable Spirit be made from Sugar; digeſt this Spirit upon a tenth Part of pure and dry Salt of Tartar for three Days; decant the Liquor, and put it to ten Times its own Quantity of a Wine made as rich as it poſſibly would ferment: Of this Preparation ſix or eight Quarts will at any Time mend, improve, and fine down a Pipe of ordinary Wine.

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a) See *Lect.* VII. *Exp.* I.
b) See *Lect.* XI. *Exp.* II. IV.

LECTURE XII.

CONTAINING

Attempts to illuſtrate and improve the Arts depending upon DISTILLATION; *viz.* Malt-Stilling, Rectifying, and Compounding.

The Subject. 1. HAVING already gone through the Arts depending immediately upon *vegetable Fermentation*, we next proceed to conſider the Ways of improving the Art of *Diſtillation*, which depends thereupon ſecondarily.

Diſtillation, what. 2. The Word *Diſtillation* is here uſed in the popular Senſe, to ſignify the Art by which all inflammable Spirits, Brandies, Rums, Arracks, and the like, are procured from vegetable Subjects, by the Means of a previous Fermentation, and a ſubſequent Treatment of the fermented Liquor by the Alembic, or Hot-Still, with its proper Worm and Refrigeratory.

The Arts therein concerned. 3. The Arts therefore at preſent to be conſidered are thoſe of Malt-Stilling, Rectifying, and Compounding, with the Buſineſs of the Brandy-Merchant, the Officers of Cuſtoms and Exciſe ſo far as relates to Spirits, and of the ſeveral Dealers in Brandies, Rums, Arracks, and Cordial Waters.

Deſign of the Experiments.

4. The Experiments we ſhall exhibit will ſhew, (1.) the Method of Diſtilling a Spirit from a fermented Malt-Wort, commonly called *Waſh*, in order to obtain *Aqua Vitæ*, or the ordinary Malt Spirit, of which many Cordial Waters are made by the Compounders, Apothecaries, and others: (2.) Our *ſecond* Experiment will exhibit the Method of purifying or rectifying this Spirit of the firſt Running, or, *Low-Wines*, as they are called, into a ſaleable Proof-Spirit, or what they emphatically call *Proof Goods*; that is, a certain ſtandard Spirit, uſually conſiſting of one half Water and the other half Alcohol: *(3.)* Our *third* Experiment will exhibit the Art of the rectifying Diſtiller, or the Method whereby the Proof Goods of the Malt-Stiller are made into a ſweeter or cleaner Spirit, for the finer Uſes of the Compounder and Apothecary: (4.) Our *fourth* Experiment will ſhew the true Method of examining Proof in Spirits, and diſcover the Invalidity of the common Methods of judging of the Purity, Genuineneſs, and Goodneſs of Brandies, Rums, and Arracks: And *(5.)* our *fifth* Experiment, will ſhew the Method of making Cordial or Compound Waters in Perfection.

EXPERIMENT I.

The Method of diſtilling Malt-Waſh, or a fermented Mixture of Meal and Malt, for Spirit.

The Diſtillation of Waſh.

5. We briſkly ſtirred together the Malt-Waſh prepared in the laſt Experiment of our laſt *Lecture*, and therewith filled two thirds of a Still, firſt made hot and dewy on the Inſide with boiling Water, and kept the whole Stirring till it almoſt begun to boil; then we immediately clapped on the Head, and luted it down. There now ſoon ran, in a ſlender Stream, from the Noſe of the Worm, a ſpirituous Liquor that was inflammable, or burnt in the Fire. We continued to work ſo long as the Liquor that came over would, when thrown upon the hot Still-Head, catch Flame from a lighted Candle applied to the riſing Fume.

Low Wines.

6. And thus we obtained what the Malt-Stillers call a *Malt Low-Wine*; that is, a ſpirituous Liquor from fermented Malt and Meal, ſo diluted with Phlegm or Water, as that the laſt Runnings of it would not burn upon the Still-Head. That which comes over after the Spirit falls off from being Proof, till it will no longer burn on the Still-Head, is called by the Name of *Faints*

The Experiment extended.

7. This Experiment may be rendered general, by a ſlight Variation of Circumſtances; that is, it may be made to ſerve as an Inſtance of all the Ways of procuring inflammable Spirits, whether Brandies, Rums, Arracks, Cyder-Spirit, or the like: For if any Wine, Beer, or fermented

Liquor from Sugar, Treacle, Roots, Fruits, &c. be treated in the ſame Manner, it will afford a Spirit differing only according to the Nature, or ſpecific Taſte and Odour, of the Subject.

8. But none of theſe Subjects will afford the leaſt drop of inflammable Spirit without a previous Fermentation *a*). Thus though the recent Juice of the Grape, or any other fermentable Juice, were diſtilled to Drineſs, yet no inflammable Spirit would be procured: Whence it appears that inflammable Spirit is a Thing produced by *Fermentation b*).

Cautions. 9. The Cautions required to render the Experiment ſucceſsful, and the Production perfect, are, (1.) That the Fermentation be well performed, and the Liquor become truly vinous, and of an acid Pungency *c*); (2.) that it be gently diſtilled, by Means of a ſoft, well regulated, Fire; (3.) that the groſſer Oil, apt to riſe along with the Spirit, be kept back by a proper Strainer, or thick doubled Flannel, laid under the Noſe of the Worm. If theſe Cautions be duly obſerved, the *Low-Wines* will prove conſiderably pure and vinous.

Management. 10. When all the Spirit is thus obtained there remains behind in the Still what they commonly call *Bottoms*; that is, the groſs Parts of the fermented Meal and Malt mixed with Water. This groſs Matter is generally uſed for the Feeding of Hogs; whence the Malt-Stillers

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a) See *Lect.* VII. *Exp.* IV.

b) See *Lect.* XI. *paſſim.*

c) See *Lect.* VII. and XI.

of *England* are commonly large Dealers in Hogs: But in *Holland* that makes a ſeparate Buſineſs.

11. Thus we have gone through three of the principal Branches of Malt Stilling; *viz.* the Brewing, Fermenting, and firſt Diſtilling Parts; or the Making of the Wort, the Working it in the fermenting Back, and the diſtilling it from the Waſh *a*). There is but one Part more of this Art, *viz.* the Rectifying Part; or the Way of *making up their Goods*, as they call it, to ſaleable Proof: And how this is performed will be ſeen by the following Experiment.

EXPERIMENT II.

The Method of ſimple Rectification, or Diſtilling the Low-Wines, produced by the foregoing Experiment, into Proof-Spirit for Sale.

Proof-Spirit. 12. We took the Low-Wines produced in the preceding Experiment, and diſtilled them over-again *in Balneo Mariæ*, or barely by the Heat of boiling Water; and thus we obtained a purer and higher rectified Spirit than before, which being let down with fair Water to a certain Size or Standard called *Proof b*), is what the Malt-Stillers underſtand by Proof-Goods, or *their* rectified Malt-Spirit.

a) See *Lect.* XI. *Exp.* VI.

b) What this Proof is, ſee explained in the fourth Experiment of the preſent Lecture.

13. The common Malt-Stillers indeed do not thus rectify their Spirit *in Balneo Mariæ*, but barely rediſtill their Low-Wines in a ſmaller Still; ſo that their Spirit is not ſo clean as that of our preſent Proceſs. The Perfection therefore of the Art of Diſtilling from Malt ſeems to require a good Method of rectifying clean, as well as a careful Obſervance of the Cautions above laid down *a*).

14. Having thus regularly gone through the whole Art of the *Malt-Stiller*, as it is practiſed by the more intelligent Artiſts, we proceed to offer a Conſideration or two for its farther Improvement.

Inconveniencies. 15. The Inconveniencies of this Art regard either the Subject, or the Work. The Subject, we ſee, is Malt; which being of a large Bulk, in Reſpect of its ſaccharine Part, and requiring a great Proportion of Water to extract this Part, hence many large Veſſels, ſuch as Maſh-Tuns, Coolers, Fermenting-Backs, Coarſe-Stills, and Fine-Stills, become neceſſary therein; whereby the Labour alſo is increaſed, and the Price of the Commodity enhanced. This Art, therefore, being far removed from Simplicity, is conſequently far removed from Perfection.

Remedied. 16. The Remedy here ſhould ſeem to depend upon the Introduction of a new Art, ſubſervient to the Art of the *Malt-Stiller*, and confining itſelf to the Boiling down of Malt-Wort to a Rob *b*), ſo as to ſupply the *Malt-Stiller* with his Subject, in the ſame Manner that the *Fine-Stiller* is now ſupplied by the Sugar-Baker

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a) See §. 9.

b) See *Lect.* X. *Exp.* III.

with Treacle: For thus the complex Buſineſs of the *Malt-Stiller* might be commodiouſly reduced to a great Degree of Simplicity.

17. By the ſame means the Spirit of the *Malt-Stiller* would alſo become much finer than at preſent; becauſe the Subject would come tolerably refined to his Hands, or purged of its groſs, mealy, and huſky Matter, which yields a diſagreeable Oil in Diſtillation; and is alſo apt to burn in the Still, and ſpoil the Spirit. We therefore recommend it to thoſe who are ſkilled in this Branch of Diſtillation, to try whether a Spirit ſuperior to that of Treacle may not be procured from the *Rob of Malt*, prudently prepared and fermented

Fine-ſtilling.

18. There needs no particular Experiment to ſhew the buſineſs of the *Fine-Stiller*; that being no more than Working, in the Manner above explained, from a Waſh made by fermenting Treacle with Yeaſt; though it is uſual to add a conſiderable Proportion of Malt, and ſometimes a little powdered *Jalap*, in the fermenting Back. The Malt accelerates the Fermentation, and makes the Spirit come out the cheaper; and the *Jalap* prevents the Riſe of any cruſty Head on the Surface of the fermenting Liquor, and ſo leaves a greater Opportunity for the free Acceſs of the Air; which alſo ſhortens the Work, by turning the foamy into the more hiſſing Kind of Fermentation.

EXPERIMENT III.

The Art of the Rectifier; or the Method whereby the Proof-Goods of the Malt-Stiller are made into a cleaner Spirit, for the finer Uſes of the Compounder and Apothecary.

Rectification of Spirits.

19. To two Gallons of the common Proof-Spirit of the Malt-Stiller, procured after the Manner of our ſecond Experiment, we added three Ounces of the Black Flux, or a Mixture of Tartar and Nitre calcined to Blackneſs *; and drew over all that would run in an uninterrupted Stream from the Noſe of the Worm, by Means of the *Balneum Mariæ*. The Spirit which thus came over we made up Proof with fair Water. And the Spirit thus prepared is the common ſaleable *Proof Goods* of the rectifying Diſtiller, when he works to a Truth.

Malt Spirit.

20. This is the Spirit we commonly meet with in Trade under the Name and Notion of *Malt-Spirit*, which is thus fitted for making the common Cordial or compound Waters; being cleared conſiderably of its fœtid Oil and nauſeous Phlegm, by Rectification. If it be deſired ſtill cleaner one of the beſt Methods is, to dilute the ſtrongeſt Part that comes over firſt, with a large Proportion of fair Water, draw off the Spirit gently again by the *Balneum Mariæ*, and then make it up proof with fine ſoft Water.

Inconveniencies.

21. But this Method will not yet give us the Spirit without ſome nauſeous and diſagreeable Flavour; nor do the Rectifiers appear acquainted with any good Method for that Purpoſe.

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* See *Lect.* II. *Exp.* II.

They have been groping after it, but generally in the dark, for want of a proper Knowledge of the Facts and Experiments neceſſary in the Enquiry. Thus, for inſtance, they ſeem little apprehenſive that it is the Oil of the Malt, reſiding in the Spirit, which occaſions all their trouble; or that it is the eſſential Oil of the Subject which gives to Malt-Spirits, Brandies, Rums, and Arracks their particular Flavours. For if the eſſential Oil could be totally ſeparated from Malt-Spirit, that Spirit might be rendered flavourleſs and taſteleſs; and then any other Flavour might, by Means of other eſſential Oils, be introduced into it; ſo that it might be made to reſemble either *French* Brandy, Rum, or Arrack. And in the effecting of this, with Simplicity and Cheapneſs, the Perfection of the Art of Rectifying ſeems to conſiſt.

Remedied. 22. For this purpoſe we would recommend the Way of Working from a Spirit largely diluted with Water, into Water again; for thus the eſſential Oil would be doubly ſeparated at one Operation. But we have no great Hopes that any Direction of this Kind can prove ſerviceable to them, while they remain unacquainted with chemical Operations, and the beſt Contrivances for Diſtilling in the large Way with Elegance and Simplicity.

23. The Chemiſts, however, have helped them to a tolerable Expedient for covering the Imperfections of the Spirit which they cannot cleanſe; *viz.* by the Addition of what is called *Spiritus Nitri dulcis*; a ſmall Proportion whereof will give an agreeable Vinoſity to a Hogſhead of Spirit. Bnt this Expedient is attended with an Inconvenience; for the Flavour is very apt to fly off, or be loſt, when the Spirit is kept in a Caſk: But the Succeſs proves different, when

the Spirit is kept and well ſtopped down in a Glaſs.

24. The Art of the *Rectifier* might be entirely ſet aſide as uſeleſs, if the original *Malt-Stiller* could make his Spirit perfect at a ſecond Operation, as we judge he might. But here again the *Malt Stillers* can ſcarce be brought to forſake the beaten Track. If they are diſpoſed to improve their Art, we would recommend to them, *firſt*, the Brewing in Perfection; and *ſecondly*, the Keeping of their Waſh, after the Manner of ſtale Beer, till it has entirely loſt its Malt Flavour, and acquired a pungent, acid, Vinoſity; and then, *thirdly*, leaving out the Lees, to diſtil with a well-regulated Fire. Thoſe who have not tried would ſcarce conceive what an agreeable Spirit may be thus procured from Malt, at the very firſt Diſtillation. The gainful Part of the Secret depends upon *an artificial Method of making Malt Liquors expeditiouſly ſtale, bright, and flavourleſs, but in other reſpects vinous* *.

Improvements.

Experiment IV.

The Method of examining Proof in Spirits; and detecting the Invalidity of the common Ways of judging of the Purity, Genuineneſs, and Goodneſs of Brandies, Rums, and Arracks.

25. We took a long Phial, half filled with the common Proof-Spirit of the *Malt-Stiller*, and giving it a ſmart Stroak with its Bottom againſt the Palm of the Hand, there appeared on the Surface of the Liquor a Chaplet, or Crown of Bubbles, which went off, or diſappeared, in a certain ſtrong Manner; that is, it firſt

Proof taken of Spirits.

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*) See *Appendix* to *Lect.* XI. See alſo *Lect.* VII.

remained a while, and then went off by Degrees, without breaking into ſmaller Bubbles, or riſing into larger. And when the Bubbles go off in this Manner, the Spirit is ſaid to be proof or merchantable *.

Erroneous. 26. And by this Kind of Proof all Diſtillers, Brandy-Merchants, Brokers, and the Officers of the Cuſtoms and Exciſe, judge of the Strength and Quality of Brandies and Spirits, in all the Brandy-Countries and Sea-Port Towns of *Europe:* whence it is alſo conveyed to other Parts of the World. It may therefore appear ſtrange to oppoſe the general Opinion and Practice, in a particular where the Intereſt of ſo many trading People, watchful againſt all Impoſition, is concerned: And yet we undertake to ſhew, that this Kind of Proof is a mere Fallacy and Deception; for if but a little vinous or ſaccharine Matter, as Treacle, Syrup, Muſt, the Rob of Fruits, *&c.* be added to a Quantity of highly rectified Spirit of Wine, this ſlight Addition will give a Brandy-Proof to that Spirit; which, therefore, by this Trial, may be made to paſs for Brandy; that is, for a Compoſition of half Water and half Alcohol, whereas in Reality it is almoſt totally Alcohol.

Detection. 27. The Fraud is eaſily detected; not in the common Way practiſed upon the *Keys*, but by burning a little of the Spirit in a Spoon; for thus it will leave the ſaccharine Matter behind in a dry Form.

Sophiſtication. 28. Whether there be any Method commonly known in *Europe*, of making a ſpirituous Liquor that contains much leſs than a half of Alcohol, to paſs current for Proof-Spirit, is not ſo certain: But doubtleſs this might be might be eaſily effected; for we ſee that Arrack is Proof, or affords a ſtrong Crown of Bubbles, upon ſhaking, as well as Brandy; yet Arrack contains not uſually above half the Quantity of Alcohol that Brandy does; and if but a Drop or two of its own or any other eſſential Oil be added to a Pint of Proof-Brandy, this is ſufficient to deſtroy its Proof, and make it appear much weaker than it is.

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* See *Lect.* VII. *Exp.* IV. § 36, 37.

Diſcovery. 30. To prevent being impoſed upon in this Way, we might have Recourſe to the *Eſſay-Inſtrument*, or *Hydroſtatical Balance.* A Gallon of Alcohol is computed to weigh ſeven Pounds and a half, and a Gallon of Water, eight Pounds; whence the compound Gravity of an equal Mixture of the two may be aſſigned. But it is a more ſure and ready Method, to burn a little meaſured Quantity of the Brandy to be tried, in a cylindrical metalline Veſſel, plunged in cold Water to an equal Height with the Brandy, and when it ceaſes to burn, exactly meaſuring the Remainder, which is the Water: Where if the Spirit has loſt one half of its Meaſure by Burning, the Brandy may be allowed Proof; if more or leſs, it muſt be judged of accordingly *.

Eſſay Liquors. 31. But beſides the falſe Method of judging of the Strength of Brandies by what is called Proof, there is another no leſs fallacious one of judging of their Genuineneſs; tho' kept a great Secret in few Hands, as a Thing ſome Dealers imagine a certain Criterion for determining whether foreign Brandies are mixed with Corn Spirits. *Its Uſe.* Theſe Dealers are provided with a certain *yellow Liquor*, a few Drops whereof being poured into a Glaſs of right *French* Brandy, gives it a beautiful blue Colour; by the Strength and Brightneſs of which Colour they judge of the Genuineneſs, or unmixed State of the Commodity, and buy upon this Kind of Proof: Whence they may come to be much deceived; for if an ordinary Malt Spirit was to be coloured with Oak, it would ſuſtain the preſent Method of Proof, and might therefore be purchaſed by theſe Dealers for *French* Brandy.

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* See a Paper by M. *Geoffroy*, to this Purpoſe, in the *French* Memoirs.

How made. 32. This Proof-Tincture, or *Eſſay Liquor*, may be expeditiouſly prepared, by diſſolving a little green Vitriol (firſt calcined to Redneſs) in a weak Spirit of Sea-Salt; which thus becomes a *yellow Liquor*, a ſingle Drop or two whereof being added to a Glaſs of any inflammable Spirit coloured yellow or brown with Oak, will inſtantly turn it of a beautiful bright Blue: Whence it is evident that this Kind of Trial is no more than a Fallacy, and only ſhews when Brandies are tinged with Oak, as they conſtantly are by lying long in the Caſk. And that it is the Oak which thus cauſes *French* Brandies to turn blue with the *Eſſay Liquor*, appears again from hence; That if the beſt and oldeſt *French* Brandy be re diſtilled, and thus made colourleſs, it will not turn blue with the *Eſſay Liquor*; becauſe all the Tincture of the Oak, or tinging Matter of the Caſk, is left behind in the Still.

Its Fallacy detected. 33. One of the beſt Methods to prevent being impoſed upon by the Mixing of Malt-Spirit with a finer, is to acquire a Habit of judging by the Taſte and Smell; for Malt-Spirit is uſually ſo ill rectified, by the Addition of fixed alkaline Salts, or certain flavouring Ingredients, that it may eaſily be perceived by the Noſe or Palate; eſpecially if the Brandy propoſed for Examination be largely diluted with Water, to prevent its over-heating the Mouth; or elſe be burnt in a Spoon, ſo as to leave the Phlegm to be taſted and ſmelt by itſelf: For this Phlegm, if the Brandy were debaſed by a Corn Spirit, will taſte and ſmell exceedingly nauſeous, very different from the Phlegm of pure *French* Brandy.

EXPERIMENT V.

The beſt Method of making Cordial or Compound Waters.

Citron Water prepared.

54. We infuſed a Pound of freſh Citron-Peel in two Gallons of good Melaſſes Spirit, and committing the whole to the Still, drew off the Spirit gently, with Care to avoid the *Faints*; then *making up*, as they call it, with ſoft Water, ſo as to leave the Liquor Proof, we added half a Pound of fine Sugar, and thus procured a genuine *Citron Water*.

The Experiment extended.

35. This Experiment is general, and ſhews the uſual Methods of making all the Compound or Cordial Waters, by thoſe Diſtillers who are called Compounders, and alſo by Apothecaries; tho' Apothecaries ſeldom make diſtilled Waters ſo good as the Compounders.

Compound Diſtillation improved.

36. The Perfection of this Branch of Diſtillation depends upon the Obſervance of a few Rules, which might be eaſily complied with: And theſe Rules we ſhall here lay down, as judging them of Conſequence to the Improvement not only of the Art of the Compounder, but alſo of a Branch of Pharmacy and Medicine.

Rules.

37. The firſt Rule is, *To uſe a well-cleanſed Spirit, that is freed from its own eſſential Oil.* For as the Deſign of compound Diſtillation is to impregnate the Spirit employed with the eſſential

Oil of the Ingredients, it ought firſt to have depoſited its own.

38. The ſecond Rule is, *To ſuit the Time of previous Digeſtion to the Tenacity of the Ingredients, or the Ponderoſity of their Oil.* Thus Rhodium-Wood and Cinnamon require to be longer digeſted before they are diſtilled than *Calamus Aromaticus*, or Lemon Peel. Sometimes alſo *Cohobation* (that is, the pouring of the Spirit once drawn off, back upon the ſame Ingredients) proves neceſſary; as particularly in making the ſtrong Cinnamon Water, where the eſſential Oil is extremely ponderous, and hardly riſes along with the Spirit, without one Cohobation more.

39. The third Rule is, *To ſuit the Fire or Strength of the Diſtillation to the Ponderoſity of the Oil intended to be raiſed with the Spirit.* Thus ſtrong Cinnamon Water ſhould be diſtilled off briſker than the Spirit of Mint or Baulm.

40. The fourth Rule is, *That a due Proportion of only the finer eſſential Oil of the Ingredients be thoroughly united or incorporated with the Spirit, ſo as to keep out the groſſer and leſs fragrant Oil.* And this may be chiefly effected by leaving out the *Faints*, and making up to ſtrong Proof with fine ſoft Water in their Stead. And upon the Obſervance of theſe four eaſy Rules the Perfection of the Art of compound Diſtillation ſeems to depend.

41. The Addition of fine Sugar to Cordial Waters is a Thing of leſs Moment, and may be uſed or omitted occaſionally. And if theſe Directions be obſerved, there will be no need of fining down Cordial Waters with Allum, Whites of Eggs, Jſing-Glaſs, or the like; for they will be preſently bright, ſweet, and pleaſantly taſted, without any farther Trouble.

42. And thus we hope to have ſhewn the Way of perfecting the Art of compound Diſtillation, even by the common Alembic, or hot Still, without the Uſe of the *Balneum Mariæ*; for which there is here no Occaſion, if the Artiſt be but expert in working by the Alembic.

AXIOMS *and* CANONS.

1. We learn from our preſent Enquiry, that inflammable Spirits are the Creatures of vinous Fermentation; or that they are actually produced, tho' not ſeparated, in that Operation *a*).

2. That the Action of Fermentation produces ſuch a Change in the Waſh, as to render it ſeparable by the Fire into ſeveral Portions of Matter, beſides the inflammable Spirit, ſpecifically different from what the Liquor would have afforded by the ſame Treatment before Fermentation *b*).

3. That at different Times of Diſtillation there come over Liquors of different Properties; and irſt of all, an extremely acrid, aromatic, and biting one; which goes off by Degrees, and ends n Acidity *c*).

4. That the Art of *Malt-Stilling* may be coniderably improved; (1.) by reducing the brewng and fermenting Parts to one Operation; 2.) by diſtilling ſlow; and (3.) by keeping back he groſs Oil of the Subject.

5. That this Art may be farther improved, y fermenting a clear, well-brewed Wort, and eeping it to be ſtale, or till it has loſt all Fla-

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a) See *Exp.* I.
b) See *Lect.* VII. *Exp.* IV. See alſo *Appendix* to *Lect.* XI.
c) See *Exp.* I. and *Appendix* to *Lect.* XI.

vour of the Malt; as it will naturally do by long lying, or in a very ſhort Time by the Help of a certain artificial Treatment *a*).

6. That the Perfection of the Art of *Malt-Stilling* requires the Aſſiſtance of a new Art, to produce a Kind of Treacle from Malt, or the Reduction of the Art of the *Malt-Stiller* to the ſame Simplicity as that of the Fine Stiller *a*).

7. That the eſſential Oil of the vegetable Subject is the Thing which gives to all Spirits their particular Odours and Flavours *b*).

8. That the fineſt, moſt ſubtil and efficacious Part of this eſſential Oil always riſes firſt in Diſtillation *b*).

9. That the Purity and Perfection of Spirits, conſidered merely as Spirits, greatly depend upon their being cleanſed firſt of the eſſential Oil, eſpecially its groſſer Part, and next of the Phlegm *c*).

20. That Brandies are a Mixture of one half Water, and the other half Alcohol; that the Meaſure of the Strength of Brandies is the Quantity of Alcohol they contain; and therefore that their Water may be commodiouſly left behind upon Exportation or Carriage *d*).

11. That as Brandies hold ſome ſmall Proportion of eſſential Oil, they are in Strictneſs dilute *Quinteſſences c*); whence their Properties and Effects may be eaſily explained, in a chemical Manner.

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a) See *Exp.* I. and III.

b) See *Exp.* I. III. V.

c) See *Exp.* I, II, III. V.

d) See *Exp.* I, II, III, IV.

12. That the Perfection of Rectifying Spirits depends upon finding out a ſimple Method of ſeparating all the Oil and Water from a Spirit *a*).

13. That the great Affinity betwixt the eſſential Oil and Spirit is the phyſical Cauſe of the Difficulty found in the Rectification of Brandies *b*).

14. That the Perfection of the Art of *Malt-Stilling*, whereby a pure Spirit might be procured at the firſt Operation, would ſuperſede the Art of Rectifying *a*).

15. That the Bubble Brandy-Proof may be artificially given to high rectified Spirit of Wine, and eaſily deſtroyed in Proof-Spirit, without weakening the Spirit *c*).

16. That the common Methods of trying and examining Brandies by the Bubble-Proof, and by their turning blue with a vitriolic Solution, are abſolutely fallacious, and not to be truſted for the Purpoſes intended *d*).

17. That *phyſical Proof* in Brandies is the Property they have, upon ſhaking, to generate a Crown of moderately large Bubbles on their Surface, by Means of a certain Tenacity, ariſing from a ſtated Proportion of eſſential Oil diſſolved in among them; which Tenacity may alſo be given by other Bodies *d*).

18. That a ſure Method of determining the Strength of Brandies is by Deflagration, or burning away their Alcohol; then examining the remaining Phlegm by Weight or Meaſure, and

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a) See *Exp.* III.
b) *Exp.* I, II, III, V.
c) *Exp.* III, IV.
d) *Exp.* IV.

comparing it with the Weight or Meaſure of the Alcohol *a*).

19. That erroneous Notions, or inaccurate and falſe Methods of Trial, may prevail, and become almoſt univerſal in Trade; ſo that even the prudent Merchant ſhall buy and ſell upon weak Trials, whilſt the Detection, Rectification, or Adjuſtment thereof, belongs to ſome other Branch of Knowledge *a*).

20. That the Way of perfecting the Art of compound Diſtillation is, (1) To procure a well-cleanſed Spirit; (2) To uſe proper Digeſtion; (3) To diſtil briſk, or ſlow, as the Subject requires; and (4) To keep back the Faints, and the groſs Part of the eſſential Oil of the Ingredients *b*).

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a) *Exp.* IV.
b) *Exp.* V.

LECTURE XIII.

CONTAINING

The Ways of procuring Vegetable Oils *and* Salts; *with their Uſes in ſeveral* Arts *and* Trades.

I.

1. WE now proceed to illuſtrate and improve the common Methods of procuring and employing vegetable *Oils* and *Salts*; on which the Exerciſe of various Arts and Trades depends. *The Subject.*

2. The Parts of Vegetables that chiefly abound with Oil are, the Seed, the Leaves, the Fruit, and the Bark. Thus the Seeds of Muſtard, and of the Sun-Flower, Almonds, Nuts, Beech-Maſt, *&c.* afford a copious Oil by Expreſſion; and the Leaves of Roſemary, Mint, Rue, Wormwood, Thyme, Sage, *&c.* the Berries of Juniper, Olives, *Indian* Cloves, Nutmeg, Mace, *&c.* the Bark of Cinnamon, Saſſafras, &c. yield a conſiderable Proportion of eſſential Oil by Diſtillation *. *The oily Parts of Vegetables.*

3. And much in the ſame Manner is Oil or Fat contained in the Parts of Animals; being either interſperſed among the muſcular Fleſh, collected into particular Bags or Cells, or lodged in the Cavities of the Bones, *&c.*

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* See below, *Exp.* II.

The Deſign of the Experiments. 4. Our *firſt* Experiment will ſhew the Method of procuring Oils by Expreſſion, from Nuts, Seeds, Maſt, Olives, *&c.* The *ſecond* Experiment will exhibit the Method of procuring thoſe called the Eſſential Oils of Vegetables. The *third* Experiment will ſhew the Method of rectifying thoſe called the Empyreumatic Oils. Our *fourth* Experiment will ſhew the Method of refining Sugar. The *fifth* Experiment will ſhew the Way of refining *Tartar* : Our *ſixth* the Manner of refining *Nitre*, or Salt-Petre; and our *ſeventh* will ſhew the Method of making Pot-Aſh.

EXPERIMENT I.

The Method of procuring Oil by Expreſſion, from Nuts, Seeds, Maſt, &c.

Expreſſed Oil of Almonds. 5. We took two Pounds of Sweet Almonds, blanched, and beat them ſmall in a Stone Mortar; then wrapping the Maſs up in a Piece of ſtrong and thick Canvas, we committed it to a ſtrong Screw-Preſs; where being ſqueezed betwixt two cold Iron Cheeks, it gradually parted with a conſiderable Quantity of Oil.

The Experiment extended. 6. This Experiment holds of all thoſe vegetable Matters that contain a copious Oil, in a looſe Manner, or in certain Cavities or Receptacles; the Sides whereof being burſt by ſqueezing, makes them let go the Oil they contain. And thus the Zeſt, or Oil of Lemon-Peel, Orange-Peel, Citron-Peel, *&c.* may be readily obtained by Preſſure, without the Uſe of Fire; for the Rinds of thoſe Fruits being preſſed green, the oily Parts will ſeparate from the aqueous, and may be rendered pure by waſhing them in fair Water *.

7. How far this Method of obtaining Oils may be applied to Advantage, ſeems not hitherto conſidered. It has been commonly applied to Olives, Almonds, Lint-ſeed, Rape-ſeed, Beech-Maſt, Ben-Nuts, Wallnuts, Bay-Berries, Mace, Nutmeg, *&c.* but not that we know of to Juniper-Berries, Cachou-Nuts, *Indian* Cloves, Pine-Apples, or Fir-Nuts, and many other Subjects that might be enumerated, both of foreign and domeſtic Growth. It has however been of late applied to Muſtard-ſeed, with good Succeſs; ſo as to extract a curious yellow, or golden-coloured Oil from that Seed, and at the ſame Time leave a Cake behind fit for making the common Table Muſtard.

8. Certain dry Matters may, as well as moiſt ones, be made to afford Oils by Expreſſion; for when they are not ſo moiſt as Almonds, or fit to be reduced to a Pulp in a Stone Mortar, they may be ground into a Meal, which, being ſuſpended to receive the Vapour of boiling Water, will thus be moiſtened ſo as to afford an Oil, in the ſame Manner as Almonds; eſpecially if the Iron Cheeks employed be firſt heated, by lying in boiling Water. And thus an Oil may be procured from Lint-ſeed, Hemp-ſeed, Lettuce-ſeed, White Poppy-ſeed, *&c.*

9. The Oils obtained by this Treatment, ſhould be ſuffered to depurate themſelves by ſtanding in a moderately cool Place, to ſeparate from their Water, and depoſite their Fæces; from both which they ought to be carefully freed. And if in this Manner they are not *Regulated.*

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* See below, § 9.

rendered ſufficiently pure, they may be well waſhed and beat with freſh Water, and then thoroughly ſeparated from it again, by the Separating-Glaſs; by which Means they will be rendered bright and clean.

10. Particular Care muſt be taken to keep ſuch of theſe Oils cool as are deſigned for eating, or for any internal Uſe; becauſe they are apt in a few Days Time to turn rancid and corroſive with the Summer's Heat, ſo as to prove very unwholeſome. Hence the Phyſician and Apothecary ſhould be cautious that the Oils given in Pleuriſies, and other Diſtempers, be freſh drawn from ſound Subjects, no way tainted, or already turned rancid, as Almonds, Piſtachios, and other Nuts, are apt to be: And again, that theſe Oils have felt no conſiderable Heat, either in the Drawing, or by ſtanding long in a warm Place. And the ſame Caution ſhould likewiſe extend to animal Oils and Fats, intended either for internal or external Uſe; ſince theſe alſo become rancid, or change to a yellow, red, or grey Colour in hot Weather, and thus become exceedingly nauſeous and corroſive; as we ſee in Butter, Bacon, and other fat Bodies, which then prove fit only for the Tallow-Chandler, or other ignoble Uſes.

Applied to other Subjects.

11. Our preſent Experiment is likewiſe applicable to the procuring of Oils or Fats from certain animal Subjects; for the Membranes, the ſkinny, and ſtringy Parts of animal Bodies, which contain much Fat, being chopped ſmall, and ſet in a Pan over the Fire, become fit for the Canvas-Bag, and by Preſſure afford a large Quantity thereof; as we ſee in the Art of Chandlery, which thus extracts the oily Matter,

leaving behind a hard Cake, or what they commonly call *Graves.*

12. Theſe *Graves*, and all the Reſiduums of the preſent Proceſs, after being ſqueezed ever ſo hard with the Preſs, will ſtill afford a copious Oil by boiling in Water; ſo that it might perhaps be more profitable for the *Tallow Chandler* to boil his *Graves* for Oil, as Bones are uſually boiled for it, than to diſpoſe of them in the ordinary Manner. And it is ſurprizing to obſerve, what a large Proportion of Oil theſe dry, and to appearance almoſt exhauſted Bodies, will yield, by repeated boiling in Water, but particularly by being committed to the *Digeſtor* *.

Farther Uſes.

13. So likewiſe if the Almonds remaining in the Canvas, after the Expreſſion of their Oil, be ground in a Mortar with warm Water, the Water will thus extract their remaining Oil, and turn therewith into a milky Liquor, or *Emulſion.* And if this Operation had been performed upon the Almonds at firſt, before we committed them to the Preſs, we might thus have got out all their Oil, and left only a dry, chaffy, or light, huſky, and exhauſted Matter behind. Whence we have a Method of diſſolving Oils in Water, and thereby of making a Kind of artificial Milk; which, by ſtanding, will afford a Cream, and turn ſour, like the Milk of Animals, but not grow rancid with Heat, like Oil. Whence ſuch Emulſions may, in ſome Caſes, be medicinally uſed with greater Safety and Succeſs than expreſſed Oils.

Oils coloured.

14. Any of theſe expreſſed Oils will receive particular Colours and Odours at the Diſcretion of the Artiſt. For Example: If a little

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* See *Lect.* VI. *Exp.* VII.

Alkanet-Root be barely infuſed in Oil-Olive, it gives a beautiful red Colour to that Oil, without altering its Taſte. So again; if a few Drops of the eſſential Oil of Cinnamon be added to a Pint of Sallad Oil, ſuch Sallad Oil may be rendered thereby agreeable to thoſe who admire the Flavour of Cinnamon. And thus may Oil, Butter, &c. be diverſified infinite Ways, by a proper Uſe of tinging Ingredients, and ſuitable chemical Oils.

Eſſences. 15. The ſame Contrivance has likewiſe its Uſes in making Eſſences for the Service of the *Perfumer*; not only where eſſential Oils are procurable, but alſo where theſe either cannot well be obtained, or but in ſmall Quantity. The eſſential Oil of Jaſmin Flowers, Honey-Suckles, Sweet Briar, Damaſk Roſes, Lilies of the Valley, &c. are either extremely dear, or ſcarcely obtainable by Diſtillation; and in ſome of them the odorous Matter is ſo ſubtil as to be almoſt loſt in the Operation. But if Jaſmin Flowers, Damaſk Roſes, Lilies of the Valley, &c. be barely infuſed in fine Oil of Nuts, or Oil of Ben, drawn without Heat, and kept in a cool Place, the ſubtil odorous Matter of the Flowers will thus paſs into the Oil, and richly impregnate it with their native odoriferous Spirit; which can ſcarce otherwiſe be procured, or ſeparated from the Flowers, without Loſs, or Debaſement. And theſe Eſſences may be rendered perfect by ſtraining off the Oil at firſt put on, letting it ſtand again, without Heat, upon freſh Flowers, and repeating the Operation twice or thrice.

What they are. 16. If we conſider the Thing attentively, we ſhall find that the Eſſences thus obtained are a Kind of *eſſential Oils*, not greatly differing from thoſe prepared by Diſtillation from the Flowers, Seeds, or Barks of odoriferous Vegetables; for all ſuch *eſſential Oils* are found to be little more than the native odorous Spirits of the vegetable Subject, wrapped up, lodged, or entangled in an unctuous or direct oily Subſtance. This oily Subſtance indeed riſes, or becomes volatile, by the Heat of boiling Water; but ſo do not the Oils gained by Expreſſion *: Whence the principal Difference betwixt thoſe *natural*, and *artificial eſſential Oils*, as we may call them, ſeems to conſiſt in the different Tenacity, Volatility, or Fixedneſs of their unctuous or direct oily Parts, the *native Spirit* appearing the ſame in both; tho' indeed it is more delicate and unimpaired in the artificial Kind of eſſential Oils, as not having felt the Force of Fire. And hence perhaps ſome conſiderable Improvements might be made in the Art of the *Oilman*, *Perfumer*, and *Apothecary*; not to mention other œconomical Uſes, and the Art of the *Dairy*.

EXPERIMENT II.

The Method of procuring the eſſential Oils of Vegetables by Diſtillation with Water.

Eſſential Oil of Juniper diſtilled.

17. We took eight Pounds of Juniper Berries, and bruiſing them in a Stone Mortar, directly put them into a Still, together with four Gallons of River-Water; then working with a briſk Fire, we drew off a Gallon of Water, and obtained along with it a conſiderable Proportion of a fragrant eſſential Oil, which we

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* See *Exp.* II. hereafter.

ſeparated from the Water by a Separating-Glaſs.

The Experiment extended. 18. This Experiment is eaſily rendered general, or made applicable to the Diſtilling of the eſſential Oils from Flowers, Leaves, Barks, Roots, Woods, Gums, and Balſams, with a ſlight Alteration of Circumſtances; as by longer Digeſtion, briſker Diſtillation, *&c.* according to the Tenacity and Hardneſs of the Subject, the Ponderoſity of its Oil, *&c.* *a*).

Uſes. 19. If the Liquor that remains in the Still, after the preſent Operation, be ſtrained, and evaporated to the Conſiſtence of Honey, it makes the *Rob of Juniper-Berries*, which may perhaps defray the Charge of the Operation, it being eſteemed a valuable Medicine, and uſed as a Strengthener of the Stomach and Inteſtines, as a Preſervative from the Stone and Dropſy, and as a Cure for the Diſorders of the urinary Paſſages.

Eſſential Oils claſſed. 20. Eſſential Oils may be divided into two Claſſes, according to their different ſpecific Gravities; ſome floating upon Water, and others readily ſinking to the Bottom thereof. Thus the eſſential Oils of Cloves, Cinnamon, and Saſſafras readily ſink; but the Oils of Lavender, Marjoram, Mint, *&c.* ſwim in Water. The lighteſt of theſe eſſential Oils is, perhaps, the Oil of Citron-Peel, which floats even on Spirit of Wine; and the heavieſt ſeems to be the Oil of Saſſafras: But the ſpecific Gravities of the intermediate eſſential Oils are not hitherto adjuſted and *tabled*, as for the Service of Chemiſtry they ought to be *b*).

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a) See *Lect.* XII. *Exp.* V.

b) See below, §. 29.

21. For obtaining the full Quantity of the more ponderous Oils from Cinnamon, Cloves, Saſſafras, *&c.* it is proper (1) to reduce the Subjects to fine Powder; (2) to digeſt this Powder for ſome Days in a warm Place, with thrice its Quantity of ſoft River Water, made very ſaline by the Addition of Sea-Salt, or ſharp with Oil of Vitriol; (3) to uſe the ſtrained Decoction, or Liquor left behind in the Still, inſtead of common Water, for a freſh Digeſtion; (4) to uſe for the ſame Purpoſe the Water of the ſecond Running, after being cleared of its Oil; (5) not to diſtil too large a Quantity of theſe Subjects at once; (6) to leave a conſiderable Part of the Still, or about one fourth, empty; (7) to uſe a briſk Fire, or a ſtrong boiling Heat, at the firſt, but to ſlacken it a little afterwards; (8) to have a low Still-Head, with a proper internal Ledge and Current leading to the Noſe of the Worm; and (9) to cohobate the Water, or pour back the Liquor of the ſecond Running upon the Matter in the Still, repeating this once or twice. *How obtained to Advantage.*

22. Theſe Cautions are all neceſſary, in order to diſtil the ponderous eſſential Oils to Profit and Perfection. The phyſical Reaſons whereon they depend may deſerve to be conſidered. (1) The Reduction of the Subject to Powder, expoſes all its Parts the better to the Action of the Water and Salt; whereby the Oil is the more mollified, attenuated, and rendered fitter to riſe along with the aqueous Vapour in Diſtillation. (2) The Digeſtion is requiſite for the ſame Reaſon; as being no more than allowing Time for this Action to be performed, in a moderate Warmth. The Water ſhould rather be the ſoft Water of Rivers, than that of Rain, which is more corruptive or fermentative; or than *Reaſons of the Caution.*

than that of Springs, which is often hard, ſo as not to mollify the Oil, but rather defend it from the Action of the Salt, or Acid; which are added not only to prevent all Tendency to Fermentation or Corruption, that would abſolutely change or deſtroy the Oil, but more particularly, as having a known Property of attenuating, liquifying, diſſolving, and purifying groſs, viſcous, and tenacious Oils. Beſides which, it likewiſe increaſes the ſpecific Gravity of the Water; whereby the Subject is now buoyed up, ſo that it cannot readily touch the Bottom of the Still, or come in the way of the Fire to be ſcorched. At the ſame Time this Addition alſo increaſes the Heat of the Liquor, or makes it exceed that of mere boiling Water; whence the Aſcent of the Oil is likewiſe promoted. (3) The ſtrained Decoction is properly uſed inſtead of Water, as being already ſaturated with oily Particles, ſo that it cannot much rob the Subject. And (4) the ſame holds alſo of the Water of the ſecond Running, which neceſſarily contains ſome oily Particles. (5) If too large a Quantity of the Subject be diſtilled at once, the Heat will neceſſarily act unequally, or be ſtrong upon ſome Parts, and weak upon others; whence, as the Oil is ſo extremely ponderous, a large Part of it will be left behind in the Subject. (6) If too much empty Space be left in the Still, it will be difficult for the ponderous Oil to aſcend; and if too intenſe a Heat be uſed, it deſtroys the grateful Odour of the Oil, without raiſing any conſiderable Quantity; and if the Still be filled too full, the Matter will be apt to boil over, and foul the Oil. (7) The Fire is ordered to be briſk at firſt, to prevent the Oil, now in ſome Meaſure ſeparated by the Heat, from going back into the Subject:

But after a Part is thus come over, if the Fire be not a little ſlackened, the Oil is apt to ſcorch, and come out at the Noſe of the Worm in the Form of a Smoke, that cannot be catched and condenſed; yet the whole Operation need not be continued long, or above two Hours, becauſe the valuable Part of the Oil ſoon comes over. (8.) If the Head of the Still be not low, the ponderous Oil will have too far to riſe; and unleſs the Oil be directed to the Worm by a proper Ledge and Current, a conſiderable Part will fall back into the Still, and ſo prolong the Operation, or leſſen the Yield. (9.) Laſtly, two or three Cohobations, or Returns of the Water upon the Subject in the Still, muſt needs bring over all the Oil that will any way riſe. And Water already ſomewhat impregnated with the Oil, is manifeſtly better for the Purpoſe than ſuch as has never been uſed before.

23. The Directions here laid down, for obtaining the ponderous eſſential Oils to Advantage, are eaſily transferred to the obtaining of the lighter: So that we need not dwell particularly upon them.

Eſſential Oils adulterated.

24. Many of theſe *eſſential Oils* being coſtly things, it is common to adulterate or debaſe them ſeveral Ways, ſo as to render them cheaper both to the Seller and Buyer. Theſe ſeveral Ways ſeem reducible to three general Kinds, each whereof has its Method of Detection; for as in *Logic* every Sophiſm has its Redargution, ſo in *Chemiſtry* every Fallacy may be diſcovered.

25. Eſſential Oils are adulterated, *(1.)* with expreſſed Oils, *(2.)* with Alcohol, and *(3.)* with cheaper eſſential Oils.

The Fraud diſcoverable.

26. *(1.)* If any eſſential Oil be adulterated with an expreſſed Oil, this is eaſily diſcovered, by adding a little Alcohol to a few Drops of the

ſuſpected eſſential Oil, and ſhaking them together: For the Alcohol will thus diſſolve all the Oil that is truly eſſential, or gained by Diſtillation, but leave the expreſſed Oil untouched; whereby the Compound of the two will be ſeparated, ſo as that their Quantities may be judged of, or the Proportion of the Debaſement found: And then by adding Water to the Alcohol, which had taken up the eſſential Oil, the Water will unite with the Alcohol, and leave the eſſential Oil ſeparable in its own Form.

27. *(2.)* If an eſſential Oil be adulterated with Alcohol, as it may be in any Proportion up to that of an equal Quantity, without being eaſily diſcoverable either by the Smell or Taſte: the Way of Detection is, to let a few Drops of the ſuſpected Oil fall into a Glaſs of fair Water; for if Alcohol be mixed with the Oil, the Water will immediately turn milky, which it would not do if the Oil were pure. And by continuing to ſhake the Glaſs, the whole Quantity of Alcohol employed in the Adulteration will unite with the Water, and leave the Oil undiſſolved behind.

28. *(3.)* The third Method above mentioned, of adulterating the richer chemical Oils, is by mixing them with the cheaper eſſential Kinds; ſuch in particular as the Oil of Pine-Wood, Oil of Turpentine, *&c.* And this is frequently practiſed, by putting Fir-Wood, Turpentine, or Oil of Turpentine, into the Still, along with the Herbs, ſuppoſe Roſemary, Lavender, Origanum, *&c.* in the ſame Manner as Diſtillers add common Malt Spirit in the Diſtilling of Wine Lees. And by this Means the Yield of an Oil may be conſiderably increaſed. But the Oils thus adulterated will diſcover themſelves in Time, by the want of their natural Flavour,

which is overpowered by that of the Turpentine, *&c.* But the quicker Detection is, to drench a Piece of Paper, or a Linen Rag, in the ſuſpected Oil, and hold the Paper or Rag before a gentle Fire; for thus the grateful Odour of the Plant will ſoon fly off, and leave only the Smell of the Turpentine, *&c.*

29. But if this Way of adulterating eſſential Oils be practiſed in Perfection, it ſeems ſcarce diſcoverable, unleſs the *Table of the ſpecific Gravities of eſſential Oils*, above recommended *, were ready at Hand. For it is known to ſome few that *Balſam Capivi* yields a large Proportion of eſſential Oil by Diſtillation with Water, even to the quantity of five or ſix Ounces from a Pound; and that this Oil is much ſweeter than any of thoſe before ſaid to be uſed for Adulteration: Whence it is eaſy by diſtilling any of the aromatic Vegetables along with this Balſam, or by mixing their Oils with the Oil of *Balſam Capivi*, to debaſe them largely, without being greatly ſubject to Diſcovery, except by the more philoſophical Chemiſts, who underſtand the uſes of the *Hydroſtatical Balance.* But it ſhould be obſerved whether, by long keeping, the chemical Oils thus adulterated with the Oil of *Balſam Capivi*, will not diſcharge the Ink of the written Label, faſtened to the containing Glaſs, as eſſential Oils adulterated with Oil of Turpentine, or other terebinthinaceous Oils, are found to do, on account of the acid Vapour that continually exhales from ſuch adulterated Oils.

30. The Methods already laid down for detecting the Sophiſtications commonly practiſed in *eſſential Oils*, are general; beſides which

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* See §. 20.

ſome Oils require peculiar Methods. Thus the eſſential Oil of Camomile Flowers may be certainly known to be adulterated with Copper and Oil of Turpentine, *&c.* if it retains its original blue Colour above a Year. The eſſential Oil of Rue, if genuine, remains fluid in the Cold, and if adulterated, congeals. And every Fact of this Kind, of which there are many already known, ſhould be duly collected: For it is certainly of great Importance to Medicine, that the genuine eſſential Oils of Vegetables ſhould be well diſtinguiſhed from the adulterated, becauſe capable of producing extremely different Effects in the Body; a Conſequence little regarded by the fraudulent Adulterator.

EXPERIMENT III.

A Method of rectifying Empyreumatic Oils.

Empyreumatic Oil ſweetned.

31. It was obſervable in our dry Diſtillations of Wood *a)*, Wormwood *b)*, and Bone *c)*, *&c.* that there always came over a groſs, fetid, empyreumatic Oil, of a nauſeous Smell, diſagreeable Colour, and abominable Taſte. To rectify this Oil, we took two Pounds thereof, and waſhed it well by the repeated Affuſion of hot Water, and ſtirring them well together, till at length the Water came away conſiderably pure; whereby the Oil was rendered leſs nauſeous both to the Smell and Taſte: Then ſetting it in an open Veſſel over the Fire, that it might diſcharge the Water lodged therein by the Waſhing, we afterwards put it into a Glaſs Retort, and drew it over in a Sand Heat; whereby it left behind a black,

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a) See *Lect.* II. *Exp.* III.
b) See *Lect.* VIII. *Exp.* II.
c) See *Lect.* VIII. *Exp.* I.

feculent, or burnt cruſty Matter, and became more fluid, ſweet, and mild.

The Experiment carried farther.

32. If the Diſtillation be repeated ten or twelve times, either in a freſh Retort every time, or in the ſame, the Oil being conſtantly returned upon its own *Fæces*, or *Caput mortuum*; theſe *Fæces* will every time increaſe in Quantity, ſo as to leave the Oil purer and thinner, till at length it becomes almoſt as thin and fluid as Oil of Turpentine, or Spirit of Wine; being extremely volatile, tranſparent, and penetrating, but ſtill of a hot, pungent Taſte, and a ſomewhat faint and diſagreeable Odour.

Uſes.

33. This Oil, obtained from an animal Subject, particularly from Blood, has been lately uſed in *England*, as a Remedy for the Epilepſy, Gout, and other obſtinate Diſeaſes, under the Name of *Oleum animale*. It was many Years ſince uſed for the ſame Purpoſes in *Germany* *. Yet doubtleſs it ſhould not be given too freely as an Internal: But, as an external Medicine, it may be of Service in reſolving hard Tumours, removing fixed Pains, &c. for it is extremely penetrating and diſcutient. And on this Account it might, perhaps, be uſed to Advantage in ſeveral Arts that require a highly ſubtilized Oil.

34. But it being chargeable to bring the groſs empyreumatic Oils to this Degree of Purity and Subtilty, many chemical Operators continue to throw them away as uſeleſs; and the rather, becauſe of that intolerably nauſeous Smell and Taſte with which they affect all Things that they touch, or come in the Way of. But as large Quantities of theſe Oils are neceſſarily obtained in the Diſtillation of Harts-Horn, Blood, &c.

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* See *Hoffman. Obſervat. Phyſico. Chym.* p. 58. 59.

it may be worth trying, whether they cannot be purified in a cheaper Manner than that above deſcribed: For Example; By drawing them over from Pot-Aſh; or, what is ſtill more profitable, by digeſting them therewith, ſo as at length to turn the Mixture, by Sublimation, into a volatile, alkaline Salt, as good as that of Harts-Horn, Blood, putrefied Urine, *&c.*

And thus much for the Subject of vegetable Oils. We next proceed to vegetable Salts.

II.

EXPERIMENT IV.

The Method of refining Sugar; or bringing the ſweet Juice of the Sugar-Cane into a white, dry, and ſolid Subſtance.

Sugar refined.

35. We took ſix Pounds of coarſe or black Sugar, as it comes unrefined from the Sugar-Colonies, and diſſolving it, over the Fire, in an equal Quantity of ſtrong Lime-Water, we added the Whites of four Eggs, whiſked up into a Froth, and ſtirred the Whole well together, in order to clarify the Sugar, after the ſame Manner as Syrups are uſually clarified; we then boiled the Liquor to a higher Conſiſtence than that of a Syrup, or till it would ſhoot grainy in the Cold. To make it do this the better, we continued to add Lime-Water at ſeveral times in the boiling. Having obtained this Point of Conſiſtence, by the Sugar-Refiners called *Proof*, we poured the whole into a Sugar-Baker's Earthen Mould, ſtopping the Hole in the lower End, and ſetting the Mould in a moderately warm Place, the Sugar, after ſome Days, *ſet* hard, or hardened; then opening the lower

Orifice of the Mould, we inverted the ſharp End into a little Pot, or *Sugar-Baker's Receiver*, and applied to the wider End, or on the Top of the Sugar, a Mixture of Tobacco-Pipe Clay and Water, made into a Kind of thin Paſte, or pappy Subſtance. And thus the Water quitting the Clay, ſoaked through the Sugar, without diſſolving the grained Part, and carried down with it only the treacly Matter, lodged betwixt the Pores of the Sugar; which treacly Matter was catched by the Receiver underneath. And thus, by keeping the Clay frequently wetting, and ſometimes renewing it, all the Treacle was got out, and a pure Loaf of White Sugar left behind; which we afterwards dried in a warm Chamber, and kept it in a dry place.

The Proceſs and Rationale.

36. The chemical Hiſtory of Sugar deſerves to be traced through all its Stages. The ripe Sugar Canes are ground down in a Mill betwixt Iron Rollers, kept continually feeding; ſo that the expreſſed Juice runs in a conſtant Stream, into its proper Receiver, from whence it is ſoon committed to the firſt boiling Pan, to prevent its turning eager: there it is boiled, ſcummed, and cleared of its groſſer and lighter Feculencies that float a-top, and alſo drawn from its heavier *Fæces* which fall to the Bottom. And thus the Juice is brought to a Kind of *Mellago*, or *Rob* *: For the Juice of the Sugar-Cane, when firſt boiled down, is like the Rob of Malt, Raiſins, the boiled Juice of the Birch or Sycamore-Tree, *&c.* and would never appear in the ſaline Form of Sugar, without ſome Contrivance to ſeparate its herbaceous, feculent Part, and a particular Addition to give it a conſiſtent Form. Both theſe Ends are anſwered by the Addition

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* See *Lect.* X. *Exp.* III.

of Lime-Water: For the Rob of the Sugar-Cane being of an acid and unctuous Nature, the Quicklime deſtroys the prevalent Acidity, diſſolves and ſeparates the groſſer unctuous Matter, and at the ſame time, combining along with the truly ſaccharine Part, gives a ſolid and dry Conſiſtence. And ſomething of this Effect Lime-Water has in every freſh Boiling; ſo that by a prudent Uſe hereof the Sugar may, after repeated Operations, or by boiling it over again with more or ſtronger Lime-Water, be brought almoſt to a cryſtalline Form. And on the Strength, Goodneſs, and Quantity of the fine Part of the Lime, thus introduced into Sugar, depends the Hardneſs, Whiteneſs, and ſhining, rocky Reſplendency of Loaf-Sugar. So that the Perfection of the Refiner's Art depends in a great Meaſure upon the prudent Choice of his Lime, and the Management of his Lime-Water.

37. The treacly Matter ſeparated from the Sugar, is collected together and boiled, ſcummed, and treated with Lime-Water again, to obtain from it all the Sugar that it will afford in a dry form. When no more can be procured from it by the Sugar-Baker, it is then called *Treacle*; being before uſually termed *Syrup*, which it perfectly reſembles: Inſomuch that a thorough Knowledge of the Art of preparing *Syrups*, with the Effects of their Different Conſiſtences, and their Diſpoſition to ferment, turn acid, or candy, and the beſt Ways of clarifying them, *&c.* may contribute to improve the Art of Sugars; and accordingly it appears, that moſt of the Improvements in the Refining of Sugars have been owing to Apothecaries and Chemiſts.

38. Sugar, thus refined, and diſcharged of its ſuperfluous oily Parts, is thereby rendered dry, thirſty, or apt to imbibe aqueous Moiſture or Oil; upon which Property depends that uſeful Invention of *Elæoſaccharums*, occaſionally mentioned above *, by means whereof we are furniſhed with a very advantageous Method of uniting Oils with Waters, Wines, Spirits, or all Manner of aqueous, vinous, or ſpirituous Liquors; ſo that ſuch Liquors may be altered in their Flavours, and improved in their Virtues, at pleaſure. For, by grinding a ſmall Proportion of any eſſential Oil with dry Loaf-Sugar, the Oil is thus rendered miſcible with any of the above mentioned Liquors, and at the ſame Time is no Way impaired, but rather improved in its Efficacy.

39. And thus we are taught an extemporaneous Method of making all thoſe ſimple and compound Waters, whoſe Virtues depend upon the eſſential Oils they contain; which is the Caſe of moſt ſimple Waters, as thoſe of Mint, Penyroyal, *&c.* Nay, ſome ſimple Waters may be procured in greater Perfection by this Means than by Diſtillation, as it is commonly performed. Thus the ſimple Water of Baulm, for Inſtance, may be made better by means of the *Elæoſaccharum of Baulm* and pure Water, than by ſimple Diſtillation, which in this Caſe brings over but little of the eſſential Oil.

40. And for compound Waters, they may be thus made to greater Perfection than we uſually meet with them. For if only the firſt Part of the eſſential Oils that comes over be ground with Sugar, and introduced into a very clean Spirit, the Cordial Waters ſo prepared will be

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* See *L. &.* XI. *Exp.* I.

no way inferior to thoſe diſtilled in the ordinary Manner. And thus Cinnamon-Water, Clove-Water, Nutmeg-Water, Citron-Water, &c. which depend upon the Uſe of but one Ingredient, may be readily made. And if compound Waters are required from ſeveral Ingredients, we need only have a compound *Elæoſaccharum* at Hand.

41. Theſe *Elæoſaccharums* alſo, as they are eaſily made, either ſimple or compound, in great Variety, might help to improve the Art of Cookery, as affording the Virtues of Aromatics in a commodious Form, for ſeveral œconomical Occaſions; and may thus be carried the longeſt Voyages without Danger of ſpoiling, or of having their Virtues impaired: an Inconvenience to which the natural Spices, though ever ſo well cured, are liable.

42. Again; A proper Set of theſe *Elæoſaccharums* might afford a Variety of ſerviceable Medicines, that ſhould have all the Qualities required in the beſt; that is, ſhould be at once ſimple, parable, efficacious, and pleaſant: For as eſſential Oils contain the ſpecific Virtues of the Subjects, or thoſe Qualities which conſtitute every Plant the Thing it is, they are of Conſequence ſome of the moſt concentrated, powerful, reſtorative, and reviving Medicines hitherto known.

EXPERIMENT V.

The Way of Refining Tartar.

Tartar refined. 43. We took two Pounds of common white Tartar reduced to Powder, and put to it five Gallons of fair Water, in an earthen Pan, and ſetting it over the Fire to boil, we in the mean Time beat up the Whites of two or three Eggs, and whiſked them in among the Liquor, which we afterwards ſkimmed and ſtrained; then ſet it to ſhoot in an earthen Veſſel, in a cool Place, for two Days, at the Expiration of which we found a Parcel of whitiſh Cryſtals ſticking to the Sides of the Veſſel.

44. This is a very troubleſome and imperfect Operation; for Tartar requiring twenty times its own Quantity of Water to diſſolve it, the Veſſels, the Fire, and the whole Apparatus, muſt of Neceſſity be large to refine a ſmall Quantity of this Salt; which yet is not ſufficiently refined at one Operation, though the Whites of the Eggs take up much dirty, and light earthy Matters, while the more ponderous ſink to the Bottom upon ſtanding. Hence the Operation muſt be ſeveral times repeated, before the Cryſtals will become perfectly white; which they will ſcarce ever do, if the Veſſel wherein the Operation is performed be metalline; and Veſſels of Earth, which this Salt does not corrode, being hard to procure ſo large as they are required for the Purpoſe, this adds to the Inconvenience. *Inconveniences.*

45. It is true, for moſt Uſes in Chemiſtry, unrefined Tartar will anſwer as well as the refined, but for the Service of certain Arts, particularly Dying, it is required thoroughly purified: So that a more commodious Method of refining it ſhould be endeavoured after, that we might at leaſt be able to refine it in *England*, as well as they do in *France*. *Remedied.*

46. Tartar is of a very particular Nature; being a ſolid and firm vegetable Salt, extremely hard to diſſolve in Water, as containing much earthy and unctuous Matters, which defend it from the Action of Water: Whence we are directed to ſoften the Body of this Salt, or looſen

its Texture, in order to its more commodious Refinement. And this End may be obtained by a prudent Uſe of Lime-Water, or a weak Lixivium of Pot-Aſh, or Salt of Tartar; as in the Making of *tartarized Tartar* *, where common Tartar is united with its own fixed Salt, and rendered eaſily ſoluble in a ſmall Proportion of Water. But there need not be ſo much Alkali uſed for this Purpoſe, as to deſtroy the Acidity of the Tartar; and if too much ſhould happen to be added, it may be mortified with Oil of Vitriol, ſo as not to prejudice the Salt.

The Experiment perfected. 47. But where an extremely pure and perfect Cream or Cryſtal of Tartar is required, we recommend the ordinary Cryſtals, or Cream of Tartar, to be diſſolved in Water, made highly acid with rectified Oil of Vitriol; for if the ſuperfluous Humidity be afterwards exhaled, the Tartar will thus ſhoot into perfectly tranſparent and beautiful Cryſtals, without at all participating of the Oil of Vitriol. And by the Help of theſe Directions common Tartar may be refined in great Perfection, and with no greater Trouble than the more ſoluble vegetable Salts.

Uſes. 48. When the Powdered Cryſtals of Tartar are mixed with half their Weight of Salt of Tartar, and diſſolved together in boiling Water, they make a very extraordinary neutral Liquor, or *Menſtruum*; and by Evaporation a neutral Salt of very uncommon Properties. This Salt eaſily runs in a moiſt Air; and will powerfully aſſiſt in extracting the reſinous or oleaginous Parts of Vegetables, by being boiled with them in Water. The aqueous Solution of this Salt will diſſolve the tough Bodies even of Myrrh, Gum-

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* See below § 48.

Lac, and is much better fitted than Salt of Tartar for many of the ſame Purpoſes where that Salt is commonly employed. This neutral Salt, or tartarized Tartar, is excellent in healing Wounds, and cleanſing Ulcers: It is an agreeable and ſucceſsful Purgative in hypochondriacal Caſes; and, diſſolved in Water, makes a pleaſant Kind of *Purging Water*. Its Virtues and Powers, both as a Menſtruum and a Medicine, ſeem not hitherto ſufficiently known; whence we recommend it to farther Experience.

Experiment VI.

The Method of Refining Nitre, or Salt-Petre.

Nitre refined.

49. We diſſolved four Pounds of rough Nitre, as it comes to us from the *Indies*, by boiling it in as much Water as would commodiouſly ſuffice for that Purpoſe; then ſet it to ſhoot for two or three Days in a covered Veſſel of Earth, with Sticks laid acroſs for the Cryſtals to adhere to. Theſe Cryſtals being afterwards taken out, were drained and dried in the open Air.

50. This ſeems to be the beſt and ſimpleſt Method of purifying Nitre; for thus, by its own natural Property of cryſtallizing, it ſhoots pure from the Sea-Salt, or other Foulneſs that is apt to mix among it. However, if the Nitre prove unctuous, it may be proper to add a little lixivium of Pot-Aſh, Lime-Water, or Allum. And if by this Means it does not become ſufficiently pure for making the beſt Gun-powder, or *Aqua Fortis*, it muſt be diſſolved again, and recryſtallized, in the Manner of our preſent Experiment; which being repeated, with a larger Proportion of Water than before, evaporating

ſlowly and ſuffering the Salt to ſhoot in a moderately warm Place, without the free Admiſſion of the external Air, the Nitre will be obtained in its utmoſt Purity and Perfection. It is judged to be pure, when being thrown upon live Wood Coals, it fulminates briſkly, and will then make perfect Gun-powder and *Aqua Fortis.*

Hiſtory of Nitre.

51. The chemical Hiſtory of Nitre is ſtill defective. This Hiſtory ſhould ſhew, by what Means Nitre is procurable from all animal and moſt vegetable Matters: For there are many Experiments and Obſervations which ſeem to prove, that Nitre originally proceeds from putrified Vegetables; that many uncorrupted vegetable Subjects contain it in a large Proportion; and that all animal Subjects contain a *ſemivolatile Nitre*; which may be rendered more fixed, or like the common, by the Addition of Pot-Aſh or Quicklime *a*).

52. To thoſe diſpoſed to enter upon this uſeful Enquiry, we recommed a full Knowledge of the Methods now in uſe for procuring Nitre from certain Earths that are dunged by Animals, and putrefied Vegetables; the ſhorteſt Ways of ſeparating the unctuous Matter from the Nitre, which occaſions all the Difficulty; and a due Compariſon of the Proceſs for procuring and refining of Nitre with that for procuring and refining of Sugar. There is Reaſon to believe, an Enquiry of this Kind might be attended with ſuch Succeſs, as to ſhew that Nitre is not peculiar to any one Country, but obtainable in Plenty, wherever animal and vegetable Subjects abound *b*).

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a) See Mr. *Lemery*'s Papers upon this Subject in the *French* Memoirs. See alſo Dr. *Stub's Legends no Hiſtories.*

b) See *Glauber's Proſperity of Germany.*

Experiment VII.

The Method of Making Pot-Aſh.

53. Having burnt a Quantity of common Billet-Wood to grey Aſhes, we took ſeveral Pounds of thoſe Aſhes and boiled them in Water, ſo as to make a very ſtrong *Lixivium*, or *Lie*. This Lie we ſtrained thro' a coarſe Linen Cloth, to keep out any black Parts of the half-burnt Wood that might happen to remain in the Aſhes; then we directly evaporated this ſtrained Lie in an Iron-Pan over a quick Fire, almoſt to Drieneſs. We took out the Matter remaining at the Bottom, and putting it into an Iron-Crucible, ſet it in a ſtrong Fire till the Matter melted; and then immediately poured it out upon an Iron-Plate, where it ſoon cooled, and appeared in the Form of a ſolid Lump of Pot-Aſh. *Pot-Aſh prepared.*

54. And much after this Manner is Pot-Aſh made in the large Way of Buſineſs, for the Service of the Soap-Boiler, Glaſs-Maker, Fuller, *&c.* But according to the Difference of the Wood or combuſtible Matter employed, with the Manner of burning it, and conducting the Proceſs, different Kinds of Pot-Aſh are prepared. *Uſe.*

55. There are certain ſaline Plants that yield this Pot-Aſh to great Advantage, as particularly the Plant *Kali*; there are others that afford it in leſs Plenty, and of an inferior Quality, as Bean-Stalks, *&c.* But in general, all vegetable Subjects afford it of one Kind or other, and may moſt of them be made to yield it tolerably perfect, after the Manner of our preſent Experiment; even the Loppings, Roots, and refuſe *And application.*

refuſe Parts of ordinary Trees, Vine prunings &c.

Difference. 56. But beſides the Difference found in different Vegetables for producing this Salt, as ſome may naturally contain more or leſs of the ſaline, oily, or earthy Principle, than others *; another Difference will ariſe from the Manner of burning the Subject, according as that is done with a greater or leſs Degree of Fire, or Admiſſion of the Air. If a vegetable Subject be burnt in a cloſe, ſtifling Manner, to a grey, or ſomewhat blackiſh or brown Aſh, theſe Aſhes thus containing more of the Oil of the Subject, will afford a more unctuous Salt, that eaſily melts in the Fire, and is better fitted for the ready making of Soap. But if the Subject be burnt in the open Air, ſo that it have every Way free Acceſs thereto, the Aſhes will be white, or contain no Part of the Oil of the Subject; and thus the Salt will difficulty melt in the Fire, and prove fitter for the making of Glaſs (where no Oil is required) than of Soap.

57. A third Difference in Pot-Aſh ariſes from the Length or Shortneſs of Time it is detained in the melting Fire; whereby it becomes either of a grey, white, bluiſh, or greeniſh Colour; grey or white if it be ſoon taken out; and bluiſh or greeniſh if long detained therein. And according to theſe Differences Pot-Aſh is more or leſs ſharp or ſtrong; a longer Continuance in the Fire always conſuming the more unctuous Parts, and leaving the ſaline ones more naked: provided no conſiderable Proportion of Earth remain mixed with the Salt, which in that Caſe would ſoon be vitrified, or turn to Glaſs, and have no ſaline Property at all.

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* See *Lect.* VIII. *paſſim.*

58. The fixed Salts of all Vegetables, when reduced to abſolute Purity, or entirely ſeparated from the other Principles, appear to be one and the ſame Thing; at leaſt not manifeſtly to differ *. Whence it ſhould ſeem that, by a ſuitable Management, good ſaleable Pot-Aſh might be made in all Places where vegetable Matters abound: For if, by examining *Ruſſia* Pot aſh, for Example, we find, that its ſuperior Excellence depends upon its being clear of Earth, or upon its containing a large proportion of Oil, or fixed Salt; theſe Advantages may, by properly regulating the Operation, be given to *Engliſh* Pot-Aſhes, ſo as perhaps to render the latter as good as the former. But where the Pot-Aſh of any remarkably ſaline Vegetable is to be imitated, as that of *Kali* ſuppoſe, we would recommend a prudent Sprinkling of the Subject with Salt or Sea Water in the Burning. And by theſe Ways properly diverſified, any Principle that is naturally wanting in the Subject might be artificially introduced, ſo as to perfect the Art of Pot-Aſh, on which the Art of Soap-making depends. *Improvement.*

59. For to make Soap requires an intimate Union of the Salt of Pot-Aſh with Oil, or any vegetable or animal Fat. This Union in the preſent Method of Soap-making is procured by a tedious Operation, or by long Boiling a weak Lie of Pot-Aſh and Quicklime with the Fat; adding a ſtronger and a weaker Lie occaſionally by degrees, till the Point requiſite to the Perfection of the Soap is hit. *Uſes in the Art of Soap.*

60. It might greatly contribute to ſhorten this Operation and eaſe the Expence thereof, if a mechanical Motion or Engine were employed inſtead of Fire, to procure this intimate Union of the *Improvement in that Art.*

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* See *Lect.* VIII.

the Lie and Oil. And that ſomething of this Kind is practicable appears from hence, that if, for Example, half a Pint of the Soap-boiler's ſtrongeſt, or *Capital Lie*, as they call it, be briſkly ſhook in a Phial, with an Ounce or more of Oil-Olive, for half a Quarter of an Hour, and then the Phial be ſuffered to reſt, there will, in a ſhort Time after, be found a ſolid Cake of tolerable Soap at the Top of the Liquor; and may be eaſily preſerved in that Form by breaking the Phial, and rendered harder by being expoſed to the Air.

Hiſtory of Soap.

71. We could wiſh that the *Chemical Hiſtory* of Soap were extant; for it ſhould ſeem that many Advantages might be thence derived to particular Arts and Trades. This Hiſtory is a Thing of larger Extent than will be generally apprehended, as containing three large Branches; (1) the *Hiſtory of Pot-Aſh*; (2) the *Hiſtory of Oils and Fats*; and (3) the *ſeveral Ways of uniting them to advantage.*

62. (1) The *Hiſtory of Pot-Aſh* would ſhew wherein the Superiority of the foreign Aſhes, particularly thoſe of *Marſeilles*, *Caſtile*, *Venice*, and *Joppa*, conſiſts; why the Soaps at preſent made in *England* fall ſhort of Perfection; and poſſibly inform us of the Ways whereby even *Joppa* Soap might be equalled in *England*. For ſuch a Hiſtory would trace out the real phyſical Differences betwixt one Sort of Pot-Aſh and another, and the Ways of converting any one of them into the reſt *, ſo as to fit them for the Soap-boiler, Glaſs maker, *&c.* reſpectively; it would ſhew how the mildeſt Pot-Aſh is obtainable, for the more curious Soaps, and eſpecially for thoſe intended to be uſed medicinally, *&c.*

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* See above, § 62—65.

And, by the Way, there is Room to ſuſpect that a thorough Enquiry into this Subject would ſhew the Matter of all Pot-Aſh to be the Matter of Nitre; or that all the Vegetables which yield Pot-Aſh by *Calcination*, might be brought to afford Nitre by *Putrefaction*; or that Pot-Aſh is nearly the ſame Thing, both in Nature and Subſtance, with *fixed Nitre* *.

63. (2) The *Hiſtory of Oils and Fats* would alſo ſhew how one Sort might be converted into another, or hard animal Fats into liquid Oils, and liquid Oils into ſolid Fats, by digeſting Oils with certain coagulating Acids, *&c.* how all the foreign ſolid Oil-Soaps might be imitated in *England*; and how a great Variety of *liquid Soaps* might be prepared for many different Purpoſes; the Foundation of the Thing entirely depending upon the Uſe of a highly ſubtilized, and thin *vegetable Oil.*

64. (3) The *Hiſtory of uniting fixed vegetable Salts with Oil*, might deſcribe ſeveral Machines for the Purpoſe; whereby many Tuns of Soap ſhould be readily made by Means of Mills, wrought by the Wind or Water; and this either with or without Fire. It might alſo inform us of ſeveral *Menſtruums*, or *connecting Mediums*, which ſhould, either alone, or with little Aſſiſtance, procure an intimate Union. And that ſomething of this Kind is practicable, we are aſſured by particular Experiments.

AXIOMS and CANONS.

1. We learn from the foregoing Enquiries, that large Quantities of Oil may lie concealed

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* See *Glauber*'s *Proſperity of* Germany; and M. *Lemery*'s Papers upon *Nitre* in the *French* Memoirs.

in Bodies apparently dry; where neither the Eye, nor any of the Senſes, can perceive the ordinary Signs of Oil *a*).

2. That Oils gained by Expreſſion are apt to turn rancid, and become unwholſome, by Heat: Whence they ſhould always be kept cool, and not be drawn by the Means of Fire, if intended for curious or internal Uſes *a*).

3. That much Oil may be ſeparated by boiling Water from Subjects that have already felt the utmoſt Force of the Preſs: Whence an Eye ſhould be had upon the Cakes of Lint-ſeed, Muſtard-ſeed, *&c.* for obtaining a farther Oil, after they have been once ſqueezed *a*).

4. That the oily Subſtance of Nuts, Almonds, and the like vegetable Subjects, is ſoluble in Water, by bare Triture, into a vegetable Milk, having a great Affinity with the Milk of Animals *a*).

5. That *expreſſed Oils* may be readily changed, or improved, in their Colours, Taſtes, and Odours; ſo as that any one of them may afford a great Variety of apparently different Kinds *a*).

6. That aromatic Vegetables yield an *eſſential Oil* by Diſtillation with Water; which Oil contains the eſſential or ſpecific Taſte, Smell and Virtues of the Subject *b*).

7. That the *native Spirits*, or fine odoriferous Parts of Vegetables, are readily imbibed, and long preſerved, by expreſſed vegetable Oils *a*).

8. That the Difference betwixt the *artificial* and *natural eſſential Oils of Vegetables*, depends upon the different Fixedneſs or Volatility of their direct unctuous Parts *b*): Whence we are directed to a Way of introducing the *native Spirits* of

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a) *Exp.* I.
b) *Exp.* II.

Plants into finer or lighter Oils than the common expreſſed Kinds; ſo as perfectly to imitate, or exceed, the natural eſſential Oils.

9. That there are ſure Methods of diſcovering ſeveral fraudulent and abuſive Kinds of Adulteration in *eſſential Oils*; but that a more curious Adulteration is practicable, ſo as to elude the common Trials *a*).

10. That every *eſſential Oil* has its determinate ſpecific Gravity: Whence, if a Table of their ſpecific Gravities were formed, from a known genuine Set, ſuch a Table might be of Service in detecting the Frauds or Debaſements frequently practiſed in theſe Oils *a*).

11. That ſeveral Cautions are required to extract the *eſſential Oils* of aromatic *Indian* Vegetables to Advantage; which Cautions being duly obſerved, ſuch Oils may be obtained in *England*, perhaps as perfect as in the *Indies a*).

12. That a highly attenuated Oil is, by repeated Rectifications, obtainable from the groſs, fetid, and empyreumatic Oil of vegetable and animal Subjects *b*).

13. That the groſs, empyreumatic, *animal Oils* may, by Digeſtion with fixed Alkalies, afford volatile Salts *b*).

14. That the Matter of *Sugar* is, originally, a vegetable Juice, apt to grow ſour with Heat, and not reducible by bare Boiling to ſolid Sugar, but only to a mellaginous or treacly Subſtance *c*).

15. That many other vegetable Juices, as particularly thoſe of the Birch and Sycamore Trees, the Rob of Malt, of Raiſins, *&c.* are convertible into good Sugars, by the ſame Means that are uſed in the ordinary Sugar-making *c*).

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a) *Exp.* II.
b) *Exp.* III.
c) *Exp.* IV.

16. That the Art of refining Sugar, ſo as to make it rocky, perfectly white, ſpangly and reſplendent, principally depends upon a prudent Choice and Uſe of Lime-Water *a*).

17. That refined Sugar renders *eſſential Oils* inſtantaneouſly miſcible with Wines, Water, and Spirits; ſo as to afford a ready Means of improving ſeveral Arts *a*): Or that the proper Introduction, Uſe, and Application of *Elæoſaccharums*, may improve the Art of Diſtilling, Pharmacy, Wines, Cookery, and Medicine *a*).

18. That the troubleſome Art of *refining Tartar* may be ſhortened and improved by the Uſe of Alkalies and Oil of Vitriol *b*).

19. That Tartar is convertible into a very different Salt, by being united with its own fixed Salt; ſo as hence to become a powerful Menſtruum, and a valuable Medicine *b*).

20. That Cryſtallization, once or twice repeated, is a ſure Method of refining Nitre, or *Salt-Petre* *c*).

21. That Nitre is not originally a foſſil, but a vegetable Salt; and thence to be found in animal Subjects *d*).

22. That a full Enquiry into practicable Methods of procuring Nitre directly from vegetable and animal Subjects, may be attended with Succeſs *d*).

23. That ſerviceable Pot-Aſh may be made in any Place that abounds with vegetable Subjects *e*),

24. That the Art of making Pot-Aſh is improveable by chemical Knowledge, to the Advantage of the ſeveral Arts thereon depending *e*).

a) *Exp.* IV. *b*) *Exp.* V. *c*) *Exp.* VI. *d*) *Exp.* VI. and VII. *e*) *Exp.* VII.

25. That in particular, the Art of Soap-making may be brought to much greater Perfection in *England*, by Means of a mixt chemical and mechanical Enquiry *a*).

LECTURE XIV.

CONTAINING

Attempts to illuſtrate and improve the Buſineſs of Colours, Dyes, *and* Stains.

The Subject.

1. OUR preſent Buſineſs is to diſcover the Means of producing, varying, changing, and deſtroying the Colours of Bodies; with a View to improve the ſeveral Arts that depend upon the Uſe of Colours, Dyes, and Stains *b*).

The Means.

2. This we ſhall endeavour to perform by Means of Experiments, firſt upon Light, and then upon ſelected Subjects of the vegetable, animal, and mineral Kingdoms; in order to find out the phyſical Cauſes of the Effects produced.

The Heads of the Experiments.

3. The *firſt* Experiment therefore will ſhew, that common Light is ſeparable into ſeveral Colours: The *ſecond* will be collective, or afford a Variety of Inſtances to prove that the Colours of Bodies depend upon a certain Diſpoſition of Parts, fitting them to reflect the differently

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a) *Exp.* VII.

b) The preſent *Lecture* was not publickly read, as the reſt were; a clear ſun-ſhiny Day, which the Experiments require, not happening at the Time.

coloured Rays of Light: The *third* principal Experiment will exhibit the Method of obtaining thoſe *vegetable Colours* commonly called *Laques:* The *fourth* will teach the Way of preparing a certain animal Colour called *Pruſſian Blue:* and the *fifth* will ſhew the Way of preparing a metalline Colour, for tinging Glaſs red, *&c.*

EXPERIMENT I.

That the Rays of Light are compounded, and ſeparable into ſeven diſtinct Kinds or Orders of Light, on which all Colours depend.

A leading Experiment, with the Priſm.

4. (1) Having darkened a Room, by ſhutting up all the Windows, and bored a ſmall Hole in a Shutter oppoſite to the Sun; if a Glaſs Priſm be now properly placed againſt this Hole, we find that an oblong and variouſly coloured Image of Light will be thrown upon the Cieling, or farther Wall of the Room. (2) If this Image of Light be carefully examined, it will appear to conſiſt of ſeven diſtinct Colours, or different vivid Lights, which are conſtantly found in the ſame Order; *viz.* Red in the firſt Place, Orange in the ſecond, Yellow in the third, Green in the fourth, Blue in the fifth, Violet in the ſixth, and Indigo in the ſeventh: But a ſlight View diſtinguiſhes only five principal Colours; *viz.* Red, Yellow, Green, Blue, and Violet. (3) If theſe ſeveral coloured Lights be ſeparately received upon another Priſm, in the ſame Manner as the Sun's Rays are by the firſt, they ſuffer no farther Diviſion, or Reſolution, but remain invariably the ſame: And this they do whatever figured Glaſs, Cryſtal, or Diamond be made uſe of. (4) But if the whole Number of

The Priſmatic Colours.

Not farther reſolvable.

Compound white Light.

of theſe differently coloured Rays be received, from the firſt Priſm, upon a *Lens*, or double convex Glaſs, in the Room, they are thus blended together again, and may be thrown upon Paper, or any other Body, placed at a due Diſtance, ſo as to form a Spot of white and bright Light in the Focus of the convex Glaſs. (5.) If the red Rays be ſeparately received by an opake white Body, that Body appears to be red; if the yellow Rays be ſeparately received in the ſame Manner, by an opake white Body, the Body appears to be yellow; and ſo of the other Colours reſpectively: A red Body appears more vivid, or intenſely red, in the red Light; a blue Body more vivid, or intenſely blue, in the blue Light, *&c.* But all coloured Bodies appear more dead or languid in Lights of different Colours from their own; as a red Body in a blue Light, *&c.*

Objects aſſume the Colour of the Light.

Light a Compound

Of ſeven Colours.

5. This general Experiment is the Foundation of Sir *Iſaac Newton*'s Doctrine of Light and Colours *; and may ſhew, (1.) that the Sun's Light is not a ſimple Thing, but compounded of ſeven different Orders of coloured Rays; all which being exquiſitely blended together, conſtitute a perfectly white Light: (2.) That theſe ſeven Orders of Rays are differently refrangible; that is, differently diſpoſed to be turned out of their Way, in paſſing from one tranſparent Body into another; the red Rays leaſt, the Violet moſt, and the reſt in their Order as mentioned above: Which is the phyſical Reaſon of the Diviſion of Light into theſe ſeven Orders of Rays, and that there are no more than ſeven original Colours of Light: (3.) That Bodies appear of the ſame Colour with

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* See his *Optics, paſſim.*

The Colours of Bodies from Light.

White and Black no Colours.

Colours of Bodies whence.

Order of Rays they reflect, or turn back, into the ſame Medium from whence they were received: (4.) That White and Black are no true Colours; but White an equal Reflection of all the original Colours, and Black the Abſorption of them all; for if they were returned, either mixed or unmixed, Whiteneſs, or ſome of the ſeven original Colours of Light, and not Blackneſs, would appear: (5.) That the Variety of Colours in natural Bodies proceeds from their differently reflecting or refracting the Rays of one, two, or ſeveral Orders, more than the reſt. Thus the Bodies denominated red chiefly reflect the red Order of Rays; thoſe denominated blue Bodies chiefly reflect the blue Rays of Light; and are thence ſaid to be red, blue, *&c.* And all the mixed Colours of natural Bodies ariſe from their reflecting two or more Orders of Rays together, and abſorbing or ſtifling the Reſt.

EXPERIMENT II.

Or, collective Inſtances to ſhew that Tranſparency, Whiteneſs, Blackneſs, and Colours, as conſidered in Bodies, depend upon certain particular Structures, Textures, or Arrangements of the Parts of Bodies; differently diſpoſing them to tranſmit, reflect, refract, or abſorb the Rays of Light.

The Texture of Bodies changed by Triture.

6. (1.) Glaſs, Cryſtal, Diamonds, Nitre, Borax, and other tranſparent ſolid Bodies, loſe their Tranſparency, and appear white, upon their being reduced to Powder; that is, by a bare Alteration of their groſs Texture, or a ſimple Reduction to ſmaller Parts, ſo as to make them reflect many of the Rays of Light which they before tranſmitted. And the ſame holds of the Whites of Eggs whiſked up to a Froth, frothy Water, *&c.*

7. Black Talc, by being made red hot in the Fire, is turned of a Gold Colour; Syrup of Violets, by a boiling Heat, loſes its beautiful Violet Colour, ſo as at length to become pale, or colourleſs; white Loaf-Sugar, being barely melted over the Fire, without Water, immediately changes its Whiteneſs, and becomes brown, or, by a longer Continuance, black; ſo that a ſingle Grain of this black Subſtance will tinge a Pint or a Quart of fair Water, or colourleſs Brandy, of a beautiful yellow, brown, or ſtraw Colour; for which Purpoſe it is uſed by Diſtillers, and others *a*). *By Fire.*

8. All the finer coloured Flowers, as Violets, Carnations, Roſes, &c. loſe their Colours barely by being expoſed to the open Air for any long Time; ſo as at laſt to appear perfectly diſcharged, or white; as if they had been expoſed to that particular Diſcharger of Colours, the Fume of burning Brimſtone. And the ſame is remarkable of the finer or lighter Kinds of Colours in Silks, or the light Blues, Yellows, and Reds, particularly the light grain-coloured Silks; all which Colours are gradually changed, diſcharged, or aboliſhed, in wearing, or by the Silks being long expoſed to the Action of the Air *b*). But the Scarlet Colour is more fixed and durable. And, in general, the deeper any Colours are, the more fixed and durable they prove; as being thus not Shades, as the Pinks, light Blues, &c. are, but true Colours, correſponding to the original Colours of Light. Add to this, that Dyers conſtantly find their Colours prove brighteſt, or ſtrike to the beſt Advantage, when the Air is clear *b*). Laſtly, the blue eſſen- *By the Air.*

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a) See *Lect*. II. and XII.

b) See *Lect*. III. *paſſim*.

tial Oil of Camomile-Flowers loſes its Colour, and changes to a dirty Green, by being expoſed to the Air.

By Water. 9. Different Waters ſtrike different Colours with the ſame tinging Ingredients. Thus irony Waters turn black, or inky, with Galls, Green Tea, &c. And Dyers find ſome certain Waters more proper for their Purpoſes than others. And, in general, the pureſt and lighteſt Waters ſtrike the beſt Colours with Dying-Stuffs. And hence it is that ſuch Waters as have, by long ſtanding, putrified, or fermented, and purged themſelves, or been filtred thro' the common Filtring-Stone, or Sand, are found to extract and communicate Colours to the greateſt Advantage *.

By Salts. 10. Salts having a Power to alter the Textures of Vegetables, do conſequently produce Changes of Colours therein Thus moſt Flowers, whether blue or red, as Violets, Roſes, &c. turn green with *Alkalies*; but Violets turn red, and red Roſes have their native Redneſs greatly hightened by *Acids*. So again, the yellow Roots of Rhubarb, Turmeric, &c. are hightened, or made redder, by *alkaline Salts*.

The Texture of Metals leſs alterable. 11. As Metals have a ſtrong Texture in their metalline Form, ſo they preſerve their natural Colours durably, unleſs corroded or diſſolved by their particular Menſtruums; after which, their Solutions ſtrike particular durable Colours, or afford the ſtrongeſt *Stains*.

Iron. 12. Iron diſſolved in ſtale Small-Beer gives the beautiful Yellow uſed in Callico-Printing; when ſublimed with *Sal-Armoniac* it alſo affords a Yellow. And the common Iron-Moulds made by Ink, are owing to the Iron diſſolved in the

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* See *Lect.* V. *paſſim.*

Copperas, whereof the common Black Writing-Ink is made.

13. Copper melted with Zink appears of a Gold Colour; diſſolved in *Aqua-Fortis* it affords a beautiful Green; and in any urinous Spirit, a beautiful Blue; and the Solutions may be reduced to dry Colours, by Cryſtallization, or Evaporation. The ſame Metal precipitated with common Salt, out of *Aqua-Fortis*, gives the Turquoiſe Colour to white Glaſs, when melted therewith. *Copper.*

14. Tin, a white, or colourleſs Metal, affords a light blue Colour, by being fluxed with Antimony and Nitre. The ſame Metal is neceſſary in ſtriking the Scarlet-Dye, with *Aqua-Fortis* and Cochineal. Its Calx turns, by ſtrong Fuſion, to a Glaſs of the opal Colour. *Tin.*

15. Lead, being corroded by the Fumes of Vinegar, makes the fine White called *Ceruſe*, and the white Fucus called *Magiſtery of Lead*; being calcined in a ſtrong naked Fire, it becomes Minium, or Red Lead; and this melted into Glaſs with Sand, is the Foundation of the Art of imitating all the coloured Gems: For this Glaſs itſelf will reſemble the Hyacinth, and by the Addition of prepared Gold and Tin, the Ruby *a*); the Sapphire with Cobalt, the Emerald with Iron and Copper, the Amethyſt with Gold, and the Granat with Iron, &c. *b*). *Lead.*

16. Silver, another white, or colourleſs Metal, being diſſolved in *Aqua-Fortis*, if Chalk is put to the Solution, turns of a beautiful Purple, or Amethyſt Colour: And its own Solution, tho' pale as Water, durably ſtains the Nails, the Skin, the Hair, and other animal Subſtances, brown or black. *Silver*

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a) See below *Exp.* V. *b*) See *Neri's Art of Glaſs*; and Mr. *Boyle's Philoſophical Works, paſſim.*

Quickſilver. 17. Quickſilver mixed with Brimſtone makes a black Maſs; and this, by Sublimation, affords the beautiful red Pigment called *Cinnabar*, or Vermillion: and the Solution of Quickſilver, being precipitated with common Salt, yields a ſnow white Powder; which alſo turns black, by being mixed with Sulphur.

Gold. 18. *Gold*, diſſolved in *Aqua Regia*, affords a fine yellow Liquor; which ſtains animal Subſtances beautifully purple: And if the Solution be ſufficiently weakened with Water, and mixed with a Solution of Tin, a fine red or purple Powder may be thus obtained for ſtaining Glaſs moſt beautifully red *a*).

Minerals. 19. Many mineral Subjects are natural Pigments; as native Cinnabar, Ochre, Black Lead, *&c.* but particularly the yellow Earth called *Light Ochre*, found in *Shottover* Hills, which is uſed native as a light Yellow, and by Calcination makes a light Red. This Colour *England* ſupplies *Italy* with; and *Le Gar* would frequently ſay he had been no Painter without it *b*).

Experimental Inſtances of Colours produced, deſtroyed, and regenerated upon ſimple Mixture.

A colourleſs Liquor affording Colours by Mixture. 20. (1) Put dry red Roſe-Leaves into Spirit of Wine, and, by ſtanding a little therein, the Roſe-Leaves will loſe their red Colour, without manifeſtly tinging or altering the Liquor; then add a little Oil, or Spirit, of Vitriol thereto, and the Liquor will appear of a red Colour. But if a little alkaline or urinous Spirit be poured to the Mixture, the red Colour preſently changes to a Green; which, by the Addition of a little

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a) See hereafter, *Exp.* V.
b) See below, *Exp.* V. § 67.

little more Spirit of Vitriol, turns to a red Colour again.

Colourleſs Liquors producing Blackneſs.

21. (2.) Make a ſlight Infuſion of bruiſed Galls in Water, ſo as not to diſcolour the Water; filtre the Infuſion; make alſo a weak Solution of Green Vitriol in Water, and filtre the Liquor, ſo that they may both appear pellucid: Theſe Liquors being now mixed together, an inky Blackneſs will immediately ariſe; but if a little Oil of Vitriol be added to the Mixture, the Blackneſs will, by Degrees, totally vaniſh, and the Liquor appear pellucid again; tho' the Blackneſs may be recalled by the Addition of a little Salt of Tartar.

A white ſolid, and pellucid Fluid, turned into Blackneſs.

22. (3.) If a little bruiſed Camphire, which is a very white Subſtance, be put into pellucid Oil of Vitriol, and the containing Glaſs be ſhook for ſome Time, the Camphire will diſſolve, and gradually change the Mixture to a Brown, and at length to a full Black. But upon the Addition of fair Water, the Blackneſs entirely vaniſhes, and the Camphire riſes to the Top in its priſtine Form, and native Whiteneſs *.

A Liquor differently coloured as differently viewed.

23. (4.) If the Shavings of *Lignum Nephriticum* be infuſed for ſome Time in cold Water, and the clear Liquor be decanted into a clean Glaſs, and viewed from the Light, the Liquor will appear of a beautiful Blue; but if viewed towards the Light, of a Yellow. If a little Spirit of Nitre be put to this Liquor, it loſes its Power of reflecting the blue Rays; but the Addition of a little Oil of Tartar, *per deliquium*, recovers that Power again.

Its Colour deſtroyed and recovered by Mixture.

Red changed into Purple by Mixture.

24. (5.) If Logwood be infuſed in Water, it gives a red Colour; which, upon the Addition

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* It is remarkable, in this Experiment, that the ſtrong Scent of the Camphire is abſolutely wanting in the black Solution; but recovered upon the Addition of the Water.

of a little Spirit of Urine, turns to a fine Purple: But this may be changed to a dilute Red, by dropping in a little Spirit of common Salt.

Red Colours hightened and lowered by Mixture.

25. *(6.)* An Infuſion of *Brazil* Wood, or Cochineal, in Water, is much hightened in its red Colour, by the Addition of Spirit of Urine; and lowered or turned paler by the Spirit of Salt.

A pellucid Liquor made blue by a white Body.

26. *(7.)* If Spirit of Wine be digeſted upon recent Camomile-Flowers, and diſtilled over from them in a Glaſs Retort, the Spirit will thus acquire a beautiful blue Colour, which may be made deeper by being drawn over again from freſh Flowers.

A blue Colour deſtroyed by Mixture.

27. *(8.)* A beautiful blue Tincture being made by digeſting Spirit of Urine upon Filings of Copper, the Addition of a little Oil of Vitriol entirely deſtroys the blue Colour; as a little Spirit of Salt turns it to a Green.

Pellucid Liquors made red by Mixture.

28. *(9.)* Pellucid Oil of Vitriol being mixed with pellucid Oil of Turpentine, or the eſſential Oil of Aniſeeds, or more particularly with Oil of Cloves, they turn thereupon into a thick, red Balſam. And ſo again, if a pellucid common Oil be, by Means of a little Wax and continued Triture, gradually mixed with fair Water, they unite into a very thick, white Subſtance, Balſam, or cold Cream.

A white Powder made yellow by Mixture.

29. *(10.)* Oil of Vitriol being diſtilled over from Quickſilver, leaves a white Powder behind; to which if Water be poured, the Powder preſently becomes of a beautiful Yellow.

The ſame Solution affording different colour'd Precipitates.

30. (11.) To a Solution of Quickſilver in Spirit of Nitre, add Spirit of Urine; and a white Powder will be precipitated: To another Parcel of the ſame Solution add Oil of Tartar *per deliquium*, and a yellow Powder will fall to the Bottom: To a third Parcel of the ſame Solution

add Spirit of Urine, and the Precipitate obtained will be of a Fleſh-Colour.

31. (12) If a clean new Pen be dipped in Spirit of Vitriol, and the common deep Blue Paper be wrote upon therewith, the Letters appear of a very bright and beautiful Red: And, in the ſame Manner, pellucid Spirit of Salt ſtains a black Hat red.

Limpid Ink appearing red.

32. (13) A pellucid Solution of *Saccharum Saturni* in Water, being wrote with, becomes inviſible upon the Paper, when dried: But the bare Fumes of another tranſparent Liquor, *viz.* an Infuſion of Quicklime and Orpiment in Water, will ſoon render the inviſible Writing black and legible. And thus thoſe commonly called Inviſible or Sympathetic Inks are made.

Inviſible Ink.

33. (14) The volatile Salt of Sal-Ammoniac, a white Body, and the Cryſtals of Copper, a green one, will, by Mixture, become Purple.

A white and green Body makes Purple.

34. (15) Salt of Steel, a green Body, and Sugar of Lead, a white one, being mixed together, the Surface of the mixt Powder will appear red; whilſt the internal Parts are of a dirty White.

A Green and White, red on the Surface.

35. (16) That original, and ſimple, as well as compound, Colours, are producible by Mixture, appears from many Experiments.

36. (17) If the Sun's Rays paſs thro' two Pieces of differently coloured Glaſs, for Inſtance, a blue and a yellow Piece, laid upon each other, and theſe Rays be received from the Glaſſes upon white Paper, they then appear of a beautiful Green.

A Green from Light paſſing thro' blue and yellow Glaſs.

37. (18) It is common with the Dyers, to dye the Cloth firſt Blue with Woad, and turn that Blue into a Green by the Yellow called *Dyer's Weed*, or *Luteola.*

Greens dyed from blue and yellow.

Green from a blue and yellow Liquor. 38. (19) To a fine yellow Solution of pure Gold, in *Aqua Regia*, add a deep blue Solution of Copper in Spirit of Urine; and the Mixture will appear green.

From blue and yellow Ammel. 39. (20) Blue and yellow Ammel, being melted together, conſtitute a green one.

Many Painter's Colours by Mixture. 40. (21) The Painters make a great Variety of compound Colours, by mixing two, three, or more different Colours together, either on their *Pallat*, or on the Canvas.

Mixed Colours may make White. 41. (22) A Mixture of the ſeven original Colours, or even five of them, will make a White; and the more perfectly, the finer and more perfect the coloured Bodies are. Thus, if a large Top be painted on its upper Surface, one Part red, another yellow, another green, another blue, and another violet; this Surface, whilſt the Top is ſpinning briſkly (ſo that the Motion ſhall confound the ſeveral Colours, or make them appear mixed to the Eye) will exhibit a dirty Kind of Whiteneſs. And in like Manner, by mixing together Powders of different Colours, as Vermillion, Orpiment, Indigo, Verdigreaſe, &c. in proper Proportions, the compound Powder will, in a ſtrong Light, appear to be white. And if differently coloured Flames could be brought to mix, this Experiment might be made in greater Perfection.

Flames of different Colours. 42. (23) Flames are of different Colours, according to the Bodies that produce them. Thus the Flame of burning Camphire is white, like the Focus of a Burning-Glaſs; the Flames of Spirit of Wine, and of Sulphur, are blue; the Flame of white Wax is white, inclining to blue; that of Tallow, white, but rather inclining to yellow, &c. Whence proceeds the Difference of the Colours of Bodies, as viewed by Daylight, Candle light, Fire-light, ſulphureous Light,

&c. And, for making Experiments to this Purpoſe, Oil might be impregnated with certain Metals, as particularly Copper and Iron, by Triture, and Digeſtion, ſo as to exhibit their particular Flames.

The Priſmatic Colours imitated.

43. (24) The Priſmatic, or original Colours may be imitated to conſiderable Perfection in Liquors, where the Parts of the tinging Subſtances are rendered extremely minute or fine. Thus a Solution of Cochineal in Spirit of Urine, viewed in a ſtrong Light, affords a moſt vivid and beautiful Red; a Solution of Copper in Spirit of Urine, yields a glorious Blue; a Solution of Verdigreaſe in diſtilled Vinegar, is an excellent Green; a Solution of Gold in *Aqua Regia*, makes a fine Yellow; an Infuſion of Violets in hot Water, affords an excellent Violet Colour, *&c.* And from a thorough Acquaintance with theſe Liquors, and the Methods of varying, mixing, and heightening their Colours, many Improvements in the Arts depending upon Colours, Dyes, and Stains, might be rationally expected.

Reſult of the Experiments.

44. (25) The foregoing Set of Experiments not only confirms the former leading Experiment made with the Priſm, but alſo Sir *Iſaac Newton*'s general *Doctrine of Colours*: For it is hence manifeſt, that ſlight mechanical Alterations in Bodies, produce, alter, or aboliſh all Kinds of Colours therein; or that all the Colours of Bodies are only original Colours of Light, differently reflected, either in a ſimple or variouſly compounded State, according to the particular Diſpoſition, Texture, Mixture, or Arrangement of the ſmall Parts of the reflecting Body, ſo as to afford that infinite Variety of Colours we meet with in natural and artificial Things.

EXPERIMENT III.

The Method of preparing the vegetable Colours called Laques.

The Laque of Turmeric. 45. Take a Pound of Turmeric-Root, reduced to fine Powder, three Pints of fair Water, and an Ounce of Salt of Tartar; put them into a glazed earthen Veſſel, and let them boil together, gently, over a clear Fire, till the Water appears richly impregnated with the Turmeric, or will ſtain a Piece of white Paper beautifully yellow; then filtre the Liquor, and gradually add to it a ſtrong aqueous Solution of Roch-Allum, till the yellow Matter is all curdled together, or precipitated: After this, pour the Whole into a Filtre of Paper; where the aqueous Part will run off, and leave a yellow Matter behind; which being edulcorated, or waſhed in the Filtre, by the repeated Affuſion of freſh Water, till the Water comes away inſipid, and afterwards dried, becomes the *Laque of Turmeric*, or a beautiful yellow Colour for Painting.

The general Way of obtaining Laques. 46. This Experiment ſhews a general Method of obtaining a Laque from all the vegetable Subjects fitted to afford it: For in the ſame Manner may a red Laque be made from Madder, Brazil, and many other dying Woods, or tinging Vegetables. But where the Colour of the Subject depends upon a very ſubtil Texture, Mixture, or Arrangement of the Parts, this Method deſtroys, or at leaſt impairs, the Colour; as particularly in Violets, Red Roſes, Carnations, *&c.* So that it ſeems applicable only to the tinging Vegetables of a ſomewhat ſtrong and firm Texture.

47. In ſome Caſes alſo a ſimpler Proceſs is ſufficient to obtain rich *Laques* particularly that beautiful red one emphatically called *Laque*; and from which the Name ſeems to be derived to the reſt. This red *Laque* is obtained barely by boiling *Stick-Lac* in Water; then filtring the Decoction, and evaporating the ſuperfluous Humidity: For the beautiful red Colour adheres to the Outſides of the Sticks broke off the Trees, along with the *Gum-Lac*; and readily communicates itſelf to boiling Water *. As ſome of this tinging Matter likewiſe ſticks to the Gum itſelf, it is proper to boil them both together: For the Gum does not prejudice the Colour, nor diſſolve in boiling Water: So that after the Operation the Gum is as fit for the making of Sealing-Wax, or other Uſes that do not require the Colour, as it was before.

The particular Laque of Stick-Lac.

48. And much after the ſame Manner is that extremely rich and beautiful red Colour called *Carmine* prepared from Cochineal and a Solution of Tin; for Carmine may be conceived as no more than the Scarlet, or Bow-Dye Liquor, concentrated, or reduced to what the Painters call a *Body*.

Carmine.

49. How far our preſent Experiment may be applicable to other Parts of the *Materia tinctoria*, ſeems not hitherto well conſidered. Doubtleſs it might afford a great Variety of *new Colours*, by a proper Extenſion and Diverſification in the *Menſtruum* and *Method*. For Example: If *Red Saunders* be digeſted warm in Spirit of Wine,

Extenſion of the Experiment.

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* The tinging Matter adhering to the Sticks and Gum is perhaps not a vegetable, but animal Subſtance; ſomewhat of the Nature of Cochineal, and depoſited in Form of an Excrement, by a certain Kind of Bees, in the *Indies*. See a Paper upon this Subject in the *French* Memoirs; ſee alſo Mr. *Boyle* upon human Blood. *Abridgm.* Vol. II. p. 481.

A red Roſin from red Saunders. the Menſtruum acquires a deep red Colour; and if drawn off by Diſtillation, leaves behind it a red, taſteleſs, and inodorous *Roſin*, that affords no Smell even upon burning, nor diſſolves in any expreſſed or eſſential Oil; yet, even in a ſmall Proportion, tinges Spirit of Wine of a full red Colour, ſo as to render it uſeful for anatomical Injections, &c.

Another from Red Wine Lees. 50. In like Manner may a particular gummy, red Subſtance, or Pigment, be obtained, by Spirit of Wine, from dried red Wine Lees; and whether the tinging Parts of the more cumberſome dying Woods and Stuffs could not be advantageouſly extracted, at the Places of their Growth, ſo as to leave their ponderous Bulk behind, and bring away only their concentrated, eſſential Colours, might deſerve the Conſideration of the Merchant, the Dry-Salter, the Dyer, the Callico-Printer, &c. It might be tried in Log-Wood, Campeche, or Brazil; in Madder, Safflore, and many other dying Woods and Stuffs, whoſe Names we ſeldom meet with but in the *Bills of Entry*.

EXPERIMENT IV.

The Way of preparing an animal Colour called Pruſſian Blue.

The Proceſs for making Pruſſian Blue. 51. Take of crude Tartar and Nitre, each four Ounces; pulverize, and mix them together; and, by Deflagration, bring them to a fixed Salt; which being powdered hot, add to it four Ounces of thoroughly dried Ox-Blood, reduced to fine Powder: Calcine the Mixture in a covered Crucible, whereof it may fill two thirds: Then lightly grind the Matter in a Mortar, and throw it hot into two Quarts of boiling Water; boil them together for half an Hour; afterwards ſtrain off the Liquor, waſh the black remaining Subſtance with freſh Water, and ſtrain as before; continuing to do thus till the Water poured off becomes inſipid. Put the ſeveral Liquors together, and evaporate them to two Quarts. Now diſſolve an Ounce of green Vitriol, firſt calcined to Whiteneſs, in ſix Ounces of Rain-Water, and filtre the Solution. Diſſolve alſo half a Pound of crude Allum in two Quarts of boiling Water; and add this to the Solution of Vitriol, taken hot from the Fire; pouring to them likewiſe the firſt Lixivium, whilſt thoroughly hot, in a large Veſſel: A great Ebullition and a green Colour will immediately enſue. Whilſt this Ebullition continues, pour the Mixture out of one Veſſel into another, and afterwards let it reſt; then ſtrain the Liquor thro' a Linen Cloth, and let the Matter, or Pigment, remain in the Strainer; from whence put it, with a wooden Spatula, into a ſmall new Pot; pour upon it two or three Ounces of Spirit of Salt; and a beautiful blue Colour will immediately appear. Let the Matter be now well ſtirred; then ſuffered to reſt for a Night; afterwards thoroughly edulcorate it by repeated Affuſions of Rain-Water; allowing a proper Time for the Precipitate to ſubſide: And thus, at length, it will become exquiſitely blue. Laſtly, let it drain upon a Linen Strainer, and dry it gently: By all which Means it becomes the Pigment that goes by the Name of the *Pruſſian Blue*.

The Cautions required in it.

52. The Succeſs of the Experiment depends greatly upon the Calcination. The Crucible is firſt to be ſurrounded with Coals, at ſome Diſtance; that it may grow gradually hot, and the Matter leiſurely flame and glow. Let this

Degree of Heat be continued till the Flame and Glowing decreaſe; then raiſe the Fire that the Matter may glow with an exceeding white Heat, and but little Flame appear above the Crucible. The Lixiviums ſhould be very hot, and mixed together with the utmoſt Expedition*.

Its Nature. 53. The Method of making this *Pruſſian Blue* in Perfection, has been held and purchaſed as a very valuable Secret, both in *England*, *Germany*, and elſewhere; but it is now got into ſeveral Hands. Its Proceſs is very extraordinary, and could ſcarce be deduced *a priori*, from any reaſoning about the Nature of Colours. It is allowed an excellent blue Pigment, and by ſome preferred to *Ultramarine*; tho' its Durability might have been ſuſpected, from the vegetable and animal Matters uſed in its Preparation, if the Colour did not ſeem wonderfully fixed by the Operation.

Many animal Matters uſed in Colours, 54. A great Variety of Colours are prepared by the Means of animal Matters; and more particularly by the Means of Urine; which, when it has ſtood to ferment, or putrify, ſerves to extract, change, or fix the natural Colours of ſome Bodies; and to heighten the Colours of others. Thus it is uſed in the preparation of the ordinary Blue called *Archil*; which chiefly comes to us from *Holland*: It is alſo uſed in the changing or fixing of *Turnſol*; ſo as to make a moſt elegant Red from the Sun-Flower: It is alſo a principal Ingredient, along with *Indigo*, in making that noble, fixed, and durable Blue, very lately diſcovered in *England*, for the ſtaining of Callico; a Colour that firſt appears Green, but

Particularly Urine.

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* See *Philoſophical Tranſactions*, N° 381.

but by waſhing with Soap changes, and fixes into a lovely Blue.

The Spirit of Urine, &c.

55. Certain chemical Preparations from animal Subjects are likewiſe employed for extracting, changing, or heightening the Colours of various Bodies. Thus the alkaline, or volatile, Spirit of Urine, Blood, Bones, *&c.* extracts a fine Blue from Copper, changes a green Solution of Copper to a Purple, and heightens the Red of Cochineal. And doubtleſs the preſent Stock of Colours might be conſiderably enlarged, or improved, by a prudent Choice of *animal Menſtruums.*

Animal Menſtruums, natural.

56. By animal Menſtruums we mean both the natural and artificial Kind: The natural are ſuch as Blood, Serum, Gall, Urine, *Saliva,* Rennet, Whey, Butter-milk, *&c.* moſt of which being properly employed, will either diſcharge or produce Colours. Thus recent Urine diſcharges the common Ink out of Linen; the *Saliva* diſcharges Red Ink; Butter-milk takes Stains and Mildews out of Linen, *&c.* Blood, we ſee by our preſent Experiment, affords a rich and beautiful Blue; and Gall is a natural Yellow; which may deſerve to be treated as Blood, in making the *Pruſſian Blue.*

And artificial.

57. Theſe natural animal Menſtruums, or other animal Subſtances, being chemically treated, may afford a great Variety both of ſimple and compound Liquors, or new artificial Menſtruums, for farther improving the Buſineſs of Colours, Dyes, and Stains. Thus, as putrified Urine affords an alkaline Spirit, by Diſtillation, that ſerves to produce, alter, or deſtroy a great Number of Colours; ſo likewiſe might the Liquors obtained, by Diſtillation, from recent, or fermented Whey, Butter-milk, *&c.* And by variouſly compounding theſe ſeveral Subſtances,

or Liquors, even by random Trials, or chance Experiments, ſome new Diſcoveries in Colours might be made; as in the preſent Example of the *Pruſſian Blue:* Tho' we have a much greater Dependence upon Experiments conducted in a rational Manner; or in the Way of an Art, formed upon a competent Knowledge of chemical Operations, with their Productions and Effects; which will enable the Enquirer to reaſon, by Analogy, from one Experiment to another; and thus lead, in a ſure and guarded Manner, to new Inventions and Diſcoveries.

The Experiment extended. 58. Thus, for Inſtance, the chemical Operator having found that common Bones, burnt only to Blackneſs, afford the Bone-black; it is eaſy to transfer the Experiment to Ivory, whereby a better Black is produced. And thus, upon finding that dried Ox-Blood has ſo great an Effect in making the *Pruſſian Bule*, we are naturally led to try the ſame Experiment with the Blood of different animals; or other concreted animal Juices, as Gall, Feathers, Fleſh, Leather, *&c.* or the entire Bodies of certain Inſects, Fiſh, Birds, *&c.* And this ſhould be done with proper Diverſifications of the Ingredients, and their Proportions; all along carefully noting the ſeveral Phænomena and Events; which will conſtantly afford Light and Inſtruction to the Mind, for the better regulating and conducting of the Enquiry, till it ends in a full Diſcovery.

EXPERIMENT V.

The Way of preparing a metalline Colour, from Gold and Tin, for tinging Glaſs of a beautiful Red.

59. Diſſolve Gold in *Aqua Regia*, and dilute the fine yellow Solution with a large Proportion

of fair Water; to the Mixture add, by Degrees, a ſufficient Quantity of a ſaturated Solution of Tin, made alſo in *Aqua Regia*; and a moſt beautiful red, or purple-coloured Powder will ſoon fall to the Bottom of the containing Glaſs. Decant the Liquor, and dry the Powder; a few Grains whereof being melted along with cryſtalline Glaſs, will tinge it throughout of an extremely fine purple or ruby Colour *a*). *The Ruby of Gold.*

60. By Means of this Experiment the ancient Art of Staining Glaſs red, long ſuppoſed to be loſt, ſeems at preſent reſtored. All the Colours are eaſily given to Glaſs, as we mentioned above *b*): But this ſeems to have been kept as a Secret in very few Hands, till lately; and may be conſiderably diverſified, ſo as to introduce a grateful Variety of beautiful red and purple Colours in Glaſs *c*). *Its Uſes, in the Art of Glaſs.*

61. It ſhould alſo ſeem that the Art of Callico-Printing, which now wants a Red, equally perfect with the Blue it has lately obtained, might hence be furniſhed with ſuch a Red; tho' there is Reaſon to ſuſpect it might come out too dear for ordinary Uſe. But as the Perfection of this Art conſiſts in diſcovering fixed, bright, and permanent Colours, not ſubject to change for the worſe in the open Air; ſuch Colours ſhould rather be expected from mineral or metallic Matters, than from thoſe of the vegetable and animal Kingdoms; which uſually afford Subjects of too lax and alterable a Texture for permanent Colours, unleſs they could be ſome way ſubſtantially fixed. *In Callico-Printing.*

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a) See *Caſſius de Auro*, p. 105.

b) See *Exp.* II. § 15.

c) See Mr. *Boyle*'s Philoſophical Works. *Abridgm.* Vol. I. p. 457—459.

The Indian *Colours how made.* 62. It appears highly probable that the *Indians*, for making the fine, bright, and durable Colours wherewith their Callicoes and Chintzes are ſtained, uſe metalline Solutions; for ſome ſtained Callicoes having been kept for forty or fifty Years, the bright Colours have been obſerved to eat out the Cloth, exactly in the ſame Manner as the corroſive, acid Spirits, which diſſolve Metals, are found to do: Whence, to imitate their richeſt and nobleſt Colours, we are directed to uſe proper metalline Solutions, made after the Manner of our preſent Experiment.

The higheſt Improvement of Colours. 63. But it would be a farther Step towards Perfection, not only in this Art, but alſo in the Art of Painting, to prepare the fineſt Colours without employing either acid or alkaline Salts; which uſually ſubject Colours to change, or elſe are apt to prey upon the Cloth, or Canvas, as we ſee in Verdigreaſe, the blue and green Cryſtals of Copper, &c. Whence we are directed, (1) to ſearch for Menſtruums that are neither acid, alkaline, or ſaline; (2) for ſuch metalline *Calxes*, Precipitates, or Powders, as will not loſe their Colours by being well waſhed, to get out their Salts; (3) to prepare certain metalline Matters by Calcination, or the bare Aſſiſtance of the Fire; and (4) to look out for *native Colours*, wherein no ſaline Matter abounds.

Variation and Extenſion of the Experiment, by Triture. 64. (1) It may be worth the trying, whether certain Metals are not ſoluble by Triture, with the pureſt Oils employed in Painting, and ſuch as contain neither acid nor alkaline Salts; or whether mere Water, the Whites of Eggs, Saliva, Gum-Water, &c. may not, by the ſame Means, be made to diſſolve them; ſo as that the metalline Particles may be left behind upon Callicoes, Cloths, &c. when the aqueous or mucilaginous Matter is dried, or waſhed away from them. But no great Effect can be rationally expected in ſuch Attempts, unleſs the Triture be long continued, and Mills, or other well adapted Engines, be uſed for the Purpoſe: For we find, in all Inſtances, that Metals muſt be reduced to very fine Particles before they will tinge or colour.

By Cryſtallization, Lotion, and Diſtillation.

65. (2) The Pigments or Colours obtained by Cryſtallization, ſuch as the blue and green Vitriols, or Cryſtals of Copper, &c. cannot be deprived of their aqueous or ſaline Parts by a dry Air, or by Waſhing, without ſuffering extreme Alterations, or being left in the Form of a groſs, terreſtrial Matter, differently coloured from what they were at firſt. Thus the fine green Cryſtals of Iron, by being expoſed to the Air, become white; and when well waſhed in Water, loſe their Greenneſs, and turn to a reddiſh or yellow-coloured Ochre, or Earth: And if deprived of their ſaline and aqueous Parts, by a ſtrong Diſtillation, they leave behind a brown or red *Caput mortuum*; which being waſhed in Water, affords not a green, but a dark-coloured Pigment, or Kind of *Spaniſh Brown*. And as this holds proportionably of other Colours obtained by Cryſtallization, there are little Hopes of procuring durable Pigments by that Operation, which ſhall be of the ſame Colours with the Cryſtals themſelves; tho', after being well waſhed, different Colours may be thus procured.

Dry Calcination.

66. (3) Metalline and mineral Matters are reducible to a conſiderable Degree of Subtilty or Smallneſs of Parts, by Fire, or dry Calcination; ſo as to leave them durably poſſeſſed of their native or adventitious Colours. Thus *Lapis Lazuli*, by being calcined, becomes the fine, durable, rich Blue, called *Ultramarine*: *Light Ochre*,

by the ſame Treatment, becomes a *light Red*; or the moſt uſeful Fleſh-Colour in Painting. *a*) Lead, by Calcination, becomes durably red; and Iron, durably brown. But a proper Method ſeems wanting for the dry Calcination of the nobler Metals, Gold and Silver: Though, for the Uſes of Gilding, *&c.* theſe nobler Metals are eaſily calcined by dipping linen Rags into their reſpective Solutions; then drying the Rags, and ſetting them on Fire, ſo as that they may burn to Aſhes; whereby a dry and fine metalline Powder is readily obtained.

New and durable mineral Pigments diſcoverable.

67. (4) Many native mineral Pigments, or durably tinging Subſtances, are already diſcovered, that do not abound with Salts; ſuch as Ochre, both yellow and red, Cinnabar, or Vermillion, Zaffora, Mangancſe, *&c.* and doubtleſs many others might be found in Countries that are ſtored with Mines, or where a proper Search is made after new mineral Subſtances *b*).

Ores tried by the ſtaining of Glaſs.

68. Our preſent Experiment likewiſe affords an uſeful Method of examining Ores, or diſcovering a ſmall Proportion of a metallic Subſtance in a large Proportion of Earth, *&c.* for a Quantity of pulverized cryſtalline Glaſs being ready at Hand, it is but mixing a little of the Ore, or mineral Matter, therewith, and melting them together; whereby the Glaſs will be deeply or lightly tinged of a certain Colour, according to the Nature and Quantity of the Metal contained in the mineral Matter. Thus a little Silver tinges white Glaſs yellow, Copper green, *&c.* Putty, or a Mixture of calcined Tin and Lead, turns it white, *&c.* tho' theſe Colours will ſomewhat vary, according to the Mixture of the metalline Matters with others, the Regulation of the Fire,

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a) See above *Exp.* II. §. 20. *b*) See ib.

and other Circumſtances: So that a Sett of particular Experiments are required, to bring this Affair to greater Certainty, and reduce the whole to a regular *Table*. But this Method, if ſufficiently verified, might be commodiouſly uſed, when the Quantity of Ore, or mineral Matter, is ſmall, or contains but a very minute Proportion of Metal; for a little metalline Matter will thus tinge a large Proportion of Glaſs.

The Art of Enamelling.

69. The Art of Enamelling in Glaſs alſo depends upon a prudent Uſe of mineral Pigments; or a Mixture of Miniature-Painting and Annealing: For the Method here is, to lay the Colours upon Glaſs, as the Painter does upon Canvas; and afterwards to ſoften the Glaſs, by a proper Degree of Heat, in the Annealing-Furnace, under a Muffle, till the Colours ſink into the Glaſs. And in this Manner alſo is Glaſs frequently coloured, on its more ſuperficial Parts, without being tinged throughout; as we ſee in the coloured Glaſs of certain Church-Windows, and ancient Buildings.

AXIOMS and CANONS.

1. The preceding Enquiry ſhews, That the *phyſical Cauſe* of the Generation, Variation, and Deſtruction of Colours in Bodies, is the different Refrangibility and Reflexibility of the different Orders of the Rays of Light *a*).

2. That Colours therefore are not inherent in the Bodies ſaid to be coloured; but rather in the Rays of Light which fall upon them; and are thence reflected to the Eye, ſo as to cauſe the *Senſation of Colour b*).

a) *Exp.* I. II. *b*) Ib.

3, That Colours, ſo far as they may be conſidered as in the Bodies ſaid to be coloured, depend upon a certain mechanical Texture, or Mixture of the ſmall Parts of Bodies; which Texture, or Mixture, being altered, or deſtroyed, the Colours alſo are altered, or aboliſhed *a*).

4. That Whiteneſs in Light is an intimate Mixture of the ſeveral Orders of Rays; and Whiteneſs in Bodies, the actual Reflection of their Rays in their natural, mixed, or unſeparated State *b*).

5. That Darkneſs is the Abſence of the Rays of Light; and Blackneſs in Bodies, not a Colour, but the Want of thoſe Rays being reflected from the Surface of the Bodies ſaid to be black; or, in other Words, that Blackneſs is produced by the Rays of Light being abſorbed, ſtifled, or drank in, by the Bodies denominated black *c*).

6. That *Tranſparency* in bodies is their Tranſmitting the Rays of Light; and *Opacity* their not Tranſmitting, but reflecting theſe rays *d*).

7. That common Light is compounded of ſeven different original orders of Rays; *viz.* Red, Orange, Yellow, Green, Blue, Indigo, and Violet; and that according as Bodies reflect more or leſs of theſe Rays, ſuch Bodies appear of different ſimple or compound Colours *e*).

8. That great Alterations of Colours are producible by a bare Alteration of the Arrangement, Texture, or Mixture of the ſmall Parts of Bodies; or by the Interpoſition of different Parts, upon bare Triture, and ſimple Mixture *f*).

9. That vegetable and animal Colours are, in general, leſs durable, or more ſubject to change,

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a) *Exp.* I. II. *b*) ib. *c*) ib. *d*) ib. *e*) ib. *f*) *Exp.* II. III. IV. V.

than the mineral Kind; on Account of the looſer, or more porous Nature and Texture of the two former, and the ſtronger and cloſer of the latter a).

10. That the Arts of Enamelling, and Imitating Precious Stones, in Glaſs, depend upon the Addition of metalline *Calxes* to the Glaſs of Lead, or pure cryſtalline Glaſs, in Fuſion; and that an infinite Variety of the moſt durable and beautiful Colours are obtainable by this Means b).

11. That many new Colours may be reaſonably expected from a proper Enquiry into, and a chemical Treatment of, various Subjects of the vegetable and animal Kingdoms c); and that there are four principal Ways of obtaining new, fixed, or durable mineral and metalline Colours; *viz.* (1) by diſcovering new *Menſtruums*; (2) by finding ſuch metalline Powders as will bear to be waſhed from their adhering Salts; (3) by properly applying dry Calcination; and (4) by enquiring after native mineral Colours that are not ſaline d).

12. That a great Variety of new and fixed Colours may be prepared from Metals, and their Menſtruums, or certain Mixtures of metalline and mineral Matters, for the farther Service and Improvement of the ſeveral Arts that depend upon Colours, Dyes, and Stains e).

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a) *Exp.* II. III. IV. V. b) *Exp.* II. V. c) *Exp.* III. IV. d) *Exp.* V. e) *Exp.* II. III. IV. V.

LECTURE

LECTURE XV.

CONTAINING

Attempts to illuſtrate and improve the common Ways of preparing Remedies.

The Subject. 1. THE Buſineſs we are now entering upon is Pharmacy; a Subject which has almoſt engroſſed Chemiſtry to itſelf: Whence many underſtand by Chemiſtry little more than the Preparation of Medicines. This Notion is countenanced by the Books of Chemiſtry generally publiſhed; which ſeldom contain more than Directions for the Making of Medicines: So likewiſe the Courſes of Chemiſtry uſually given, turn chiefly upon the Application of Chemiſtry to Pharmacy.

2. That Chemiſtry is applicable to the Illuſtration and Improvement of many other Arts, hath we hope been ſhewn in the preceding Lectures. But as the Application of it to Pharmacy is a Thing of Importance to Life and Health; and as Men generally think that this is the principal Office and Uſe of Chemiſtry; we judge it proper to beſtow two Lectures upon the Subject: In the firſt whereof we propoſe to conſider the preſent State of Pharmacy, with the Means to improve it, upon the footing it now ſtands; and in the ſecond we will endeavour to ſhew how it may be reduced to a greater Degree of Simplicity; and thus be brought nearer to Perfection: The one we may call the *copious*, and the other the *conciſe* Method of Pharmacy.

3. We define *Pharmaceutical Chemiſtry*, the Art of directing and performing the ſeveral Proceſſes or Ways of Working, whereby natural Subſtances are reducible to uſeful Medicines. *Pharmaceutical Chemiſtry.*

4. And thus the whole Art conſiſts of two Parts, a *Theory*, and a *Practice*: The Theory is claimed by the Phyſician, and the Practice is turned over to the Apothecary.

5. Moſt of the natural Bodies being ſome Way or other employed as Subjects of Pharmacy, the *Materia medica* is extremely large, and its Operations various. Its Materials in the earlieſt Ages indeed were few, and the Ways of managing them ſimple: Subjects afterwards multiplied, Operations increaſed, and at preſent we ſeem abundantly ſtocked with both ſimple and compound Medicines. *Hiſtory of Pharmacy.*

6. But the Hiſtory of Pharmacy may deſerve to be more particularly traced, in order to ſee by what Means it arrived at its preſent State, and how it may be farther advanced.

7. Diſeaſes muſt have begun very early, if the firſt Inhabitants of the World experienced the ſame Changes of Seaſons, breathed the ſame Kind of Air, and uſed a like Diet and Regimen of Life with ourſelves. But ſoon after a Diſeaſe afflicts, the Patient ſeeks for a Remedy: Whence we may reaſonably ſuppoſe that this was the Foundation of Pharmacy in various Parts of the World.

8. Experiments being thus multiplied, and the Event gradually introducing better Methods of preparing the Simples, Pharmacy would begin to appear in the form of an Art: Yet when *Hippocrates* came to compile a Kind of Syſtem of Phyſic from the Obſervations of Antiquity, he deſcribed but few Preparations, and thoſe were generally ſimple.

9. Succeeding Phyſicians enlarged the *Materia medica*: *Galen* conſiderably ſwelled the Catalogue, which received many Additions from the *Arabians*.

10. And when Learning began to revive in *Europe*, the *Materia medica* was again enlarged, and great Changes wrought upon it by Chemiſtry: Whence Chemiſtry at length was generally received, and acknowledged to be of uſe in Pharmacy.

11. Both the Galenic and Chemical Part of this Art are now extremely copious. Neceſſity gave the Occaſion; Nature ſupplied the Materials; and Art and Obſervation diſcovered their Preparations, Virtues, and Uſes.

12. Thus we at preſent ſeem provided with a Competency of ſtanding Medicines; and have, by Degrees, acquired a Method of preſcribing in *extemporaneous Forms*.

13. The Art of Pharmacy may be conſidered as under the Management of Phyſicians, Apothecaries, trading Chemiſts, and Druggiſts.

14. It is the Office of the Phyſician to direct the Medicines, or give Rules for extracting, compounding, and managing the Simples. If the Phyſician therefore ſhould be defective in this Part, let the Apothecary, the trading Chemiſt, and the Druggiſt, be ever ſo juſt, or ever ſo knowing, the Art of Pharmacy muſt fall ſhort of Perfection.

15. To the Apothecary belongs the Reduction of the *Materia medica* into certain Forms of Medicines, according to the Direction of the Phyſician.

16. But there are two Kinds of Apothecaries, vulgarly known by the Names of *wholeſale* and *retail* Apothecaries. It is the latter alone we are here concerned with: Theſe act by Rule,

generally follow their Standard, and compound with Art and Care; tho' they will ſometimes ſubſtitute a *quid pro quo*, and now and then venture to reverſe an Order. In Proportion to their Skill and Care they are more or leſs liable to be impoſed on by the Druggiſt and the trading Chemiſt; all of them uſually ſelling what they buy. But if the Apothecary be often deceived by them, how ſtands it with the Patient and Phyſician? or what is the State of Pharmacy?

17. The retail Apothecaries, however, deal more in *Subſtitution* than in *Sophiſtication*. The prudent Phyſician therefore preſcribes what is uſually kept, and proper to keep, in the Shops, or what is otherwiſe eaſily obtainable. If there are other Abuſes committed in this Part of Pharmacy, they may perhaps be chiefly attributed to ſome Want of Skill or Conduct in the Phyſician.

18. The Deſign of the trading Chemiſts and Druggiſts is to furniſh medicinal Matters to the Apothecary, who cannot always detect an artful Counterfeit, or a dexterous Sophiſtication: And perhaps many Remedies, well deſigned by the Phyſician, have failed, or had miſchievous Effects, upon this Account.

19. This is propoſed as a ſhort Intimation of the preſent State of Pharmacy in *England*. If the Art be found more perfect in other Nations, it may perhaps be chiefly owing to this, That their Phyſicians are well acquainted not only with the Theory, but alſo with the Practice thereof; two Things which ſhould never be ſeparated, as being in Reality but one effective Thing conſiſting of two Parts; *viz.* previous Notion, and Execution.

20. What uſeful Addition or Reformation the *Materia medica* is capable of receiving, no one

at preſent can ſay. If a ſtrict Enquiry were made, perhaps it might be found proper to throw out of our preſent Collection a conſiderable Number of Materials, to make Room for others of greater Efficacy. But this is no Work for private Perſons. Our preſent Buſineſs is to ſee whether any Improvements may be made in the Ways of preparing the common Medicines of the Shops.

Deſign of Pharmacy. 21. And for the better regulating of our Enquiry it may be of ſome Service to lay down two larger Obſervations; *viz.* (1) That the Deſign of Pharmacy is to ſeparate from Bodies the more medicinal Parts with which they are naturally endowed; and, upon Occaſion, to mix ſuch of them together as will beſt anſwer the curative Intentions. All in the Power of Art is only to ſeparate and mix, or differently modify; it is Nature alone that is able to produce. Pharmacy therefore conſiſts in *Analyſis* and *Syntheſis* *.

Rules. 22. (2) As it is the Perfection of Art to copy Nature juſtly, ſo by reſolving Bodies into their Principles we obtain a general Rule for Compoſition, and ſee the ſeveral Steps we ought to take in it. Nature ſhews us that in all mixed Bodies there is a Baſis or *Subſtratum*; ſomething to ſupport and envelope the other Ingredients. Thus natural Salts are the diluted with Water; the Oils with both; and all together compoſe one uniform and elegant Whole. To preſcribe juſtly, therefore, we ſhould imitate Nature: If we compound without Regard to this Rule, the Ingredients will appear huddled together, as if it were by Chance; and, inſtead of preſerving and aſſiſting, they will often clog, encumber, and deſtroy each other.

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* See *Lect.* VIII. and IX.

The Intent of the Experiments.

23. We now proceed to our Experiments, by which we propoſe to illuſtrate and improve (1) the common Method of diſtilling Simple-Waters; (2) the common Method of preparing Tinctures; (3) the Method of preparing Syrups; (4) the Method of making Electuaries; and (5) the Method of making compound Oils, Unguents, and Plaiſters: Thus propoſing to touch upon the chief Articles of the preſent *Galenical Pharmacy*, as it is vulgarly called; tho' in Reality it be no leſs *chemical* than the other.

EXPERIMENT I.

The beſt Way of diſtilling Simple-Waters.

Simple Waters, how diſtilled.

24. We took as much dried Mint, cut ſmall, as filled two thirds of our Still; then adding a Quantity of Rain-Water ſufficient to make the Plant float commodiouſly, yet leaving a fourth of the Still empty, we digeſted a while with a gentle Heat; then worked the Still, drawing off only ſo long as the Water appeared thick or milky, and taſted rich and grateful; whereby we obtained a *Simple Mint-Water* in tolerable Perfection.

The Experiment extended.

25. This Experiment, with a few occaſional Alterations, may ſhew a general Method of obtaining Simple Waters in their greateſt Perfection. The Subjects beſt fitted for it are thoſe of the odorous, aromatic, and oily Kind; tho' ſome others alſo may perhaps communicate particular Virtues to the Water: Among the fitteſt may, however, be reckoned, *Angelica*, *Anniſeed*, *Baulm*, *Calamint*, *Cinnamon*, *Cloves*, *Fennel*, *Hyſop*, *Roſemary*, *Tanſey*, *Wormwood*, &c. but parti-

cularly Pepper-Mint, which affords an extremely aromatic, pungent, and agreeable Water, good againſt the Cholic, and many other Diſorders of the Stomach and Bowels; though its Uſe is, perhaps, too little known.

Cautions. 26. It is a principal Caution, in this Operation, to remove the Receiver before the more pellucid, acid, faint, and dead Water comes over, as it ſoon will do; and if ſuffered to mix among the reſt it is apt to ſpoil the whole, by giving it a vappid or faint Taſte, and ſometimes a Degree of Acidity, or vitriolic Stypticity, and an emetic Quality; for Part of the eſſential Salt of the Plant, which now begins to riſe, uſually corrodes the Copper Head of the Still, and carries over with it ſome Particles of the Metal. Hence theſe Waters ſhould be diſtilled either with a Glaſs Head, or one of Pewter, or well tinned Copper; or elſe the Operation ſhould be carefully watched, that the ſecond Running may not mix with the firſt. The greater Care ſhould be taken, becauſe ſome Patients, more particularly Children and thoſe of a tender Habit, have ſuffered thro' a Neglect herein; and been vomited, purged, and griped by the Uſe of a Simple Water, contrary to the Intention.

Regulation. 27. The Simple Waters diſtilled after the Manner of our preſent Experiment may in many Caſes prove too ſtrong to be uſed alone; but then it is eaſy to let them down to the proper Strength with common diſtilled Water: And this is, beyond all Compariſon, better than to mix ſuch Waters with their own Faints, or Liquor of the ſecond Running.

Improvements. 28. Two Improvements might be made in this Method of obtaining Simple Waters: The firſt, by means of Cohobation and Digeſtion; the other, by means of a previous Fermentation of the Plant. With regard to the firſt; If the Liquor remaining in the Still be expreſſed from the Herb, and returned, along with all the Water that came over, upon a freſh Quantity of the ſame Subject, and they be digeſted together in a gentle Heat for two Days, and then diſtilled as before, the Water thus obtained will be much richer and more efficacious than the former: And if the ſame Proceſs be repeated two or three Times, thoſe who have not tried would ſcarce imagine how rich a Simple Water may be thus procured. This Method we would particularly recommend for making the Simple Water of Baulm, Elder-Flowers, Roſes, Camomile, and ſuch Subjects as are but ſparingly furniſhed with eſſential Oils; for otherwiſe they make but indifferent Waters.

29. The other Means of improving Simple Waters is by uſing a previous, imperfect Fermentation: This is performed by adding to the Plant and Water, put together as in our preſent Experiment, a tenth or twelfth Part of Sugar or Honey, or elſe a fortieth Part of Yeaſt; then ſetting the whole in a warm Place to ferment for two or three Days only, ſo that the Herb may not fall to the Bottom, nor the Fermentation be above half finiſhed: the whole being afterwards committed to the Still, a Water may, at one Operation, be obtained extremely rich, or impregnated with the full Virtue of the Plant. And thus may Simple Waters be made fit for long keeping without ſpoiling; the ſmall Proportion of inflammable Spirit generated in the Fermentation ſerving excellently to preſerve them. And theſe two Methods ſeem applicable to the Improvement of all thoſe Simple Waters commonly found in the Shops.

30. We ſhould next proceed to ſhew the Method of perfecting or improving Compound Waters, if we had not already endeavoured to do it in our *Lecture* upon Diſtillation by an Example in *Citron-Water* *.

EXPERIMENT II.

The beſt Way of making light Tinctures, and Infuſions.

Light Tinctures prepared. 31. We took half an Ounce of the Rind of *Seville* Orange ſhaved thin, half a Dram of Gentian-Root thin ſliced, a Scruple of the Tops of *Roman* Wormwood, half a Dram of Cardamums, and half a Dram of Cochineal, each of them lightly bruiſed: Theſe Ingredients we put to ſteep for a night in a Pint of *French* Brandy, and filtred the Liquor the next morning.

Regulation. 32. This Experiment is general, and not performed for its own Sake, but to ſhew the Method of making all Kinds of the lighter and finer Tinctures and Infuſions without Fire, which would here prove prejudicial. The Preparation itſelf is, however, a good Stomachic Bitter, of the ſame general Nature with thoſe commonly ſold under the name of *Stoughton's Elixir*. The Excellence of theſe Preparations depends not more upon the Choice and Goodneſs of the Ingredients, than upon the Manner of their being infuſed; For if ſuffered to remain too long in the Menſtruum, or if Heat be uſed in extracting the Tincture, the groſs, terreſtrial, and nauſeous Parts of the Ingredients will be fetched out, and the Tincture thus be loaded with a heavy inert Matter, of little Virtue. But if the Infuſion be made in the Cold, and the Liquor ſtrained off ſoon, only the finer and more ſpirituous Parts of the Ingredients will be imbibed by the Menſtruum; whence the Preparation will not only taſte and ſmell more brisk and agreeable, but alſo have a much greater Virtue and Efficacy. But if, thro' the Shortneſs of their Continuance in Infuſion, the Ingredients ſhould not have ſufficiently impregnated the Liquor, the beſt Method is to pour it again upon freſh Ingredients, and again to ſtrain it off, without letting it ſtay too long upon them, or applying the Heat of the Fire. And thus, by repeated Affuſions of the ſame impregnated Menſtruum upon freſh Ingredients, an Infuſion or Tincture may be obtained, of almoſt any Degree of Strength or Richneſs, without containing the groſſer or more inactive Parts of the Ingredients, but only what may be called their finer Spirit or Quinteſſence. And this is no inconſiderable Secret both in Chemiſtry and Pharmacy; and may deſerve Regard of thoſe who deſire to procure the full Virtues of the Simples, unaltered in their Nature, yet exalted or concentrated to ſuch a Degree, that a few Spoonfuls of the Liquor ſhall contain the Spirit or Quinteſſence of a Pound of a Plant. And this is an Effect not to be expected from the Fire, which almoſt conſtantly alters the Nature of Things committed to it; nor can a valuable Eſſence of Violets, Jaſmin, Lilies, Borage-Flowers, or any Flower or Plant of an extremely fine odoriferous Spirit, be procured by Heat, tho' it readily may by ſteeping theſe Flowers in cold Water, cold Vinegar, cold Wine, or the like; and frequently pouring the Tincture upon freſh Flowers, till the Liquor becomes ſtrongly impregnated.

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* See *Lect.* XIII. *Exp.* V.

33. Apothecaries uſually commit the ſame Error in preparing the finer Tinctures, that they do in making their Cordial Waters; in both Caſes ſaturating the Liquor with the groſſer, more uſeleſs, and leſs ſpirituous Parts of the Ingredients; whence the Cordial Waters of the Shops too often abound with a groſs, heavy, diſagreeable Oil; and the Tinctures of the Shops with a groſs, heavy Earth, or Kind of bituminous Matter, inſtead of a brisk, lively, and invigorating Spirit; which alone is the Thing required in both Caſes.

34. This Doctrine of Tinctures and Infuſions ſhould be reduced to Rule for the Improvement of Chemiſtry, which will never be perfected till it can extract, ſeparate, and concentrate, the Virtues of Things unimpaired, or unaltered in their Nature. And doubtleſs it would prove a very ſerviceable Thing in Chemiſtry, Medicine, and Natural Philoſophy, to know the beſt and eaſieſt Ways of concentrating the Virtues of Bodies unaltered: And this may, in ſome Meaſure, be effected by our preſent Method, and the Uſe of well a dapted Menſtruums: For, in general, (1) a quick and cold Infuſion extracts the Spirit of Vegetables; but a long and hot one confounds, impairs, or deſtroys it. (2) To repeat quickly thecold Infuſion of a freſh Subject in the ſame impregnated Menſtruum, ſeems greatly to collect and concentrate the Spirit, that is, the finer and more eſſential Part of Bodies. (3) The proper Menſtruums for this Purpoſe ſeem to be ſuch as pure Rain-Water, Vinegar, Wine, Water mixed with a little fine Alcohol, Water and a little Sugar; and for certain Uſes, the common atmoſpherical Air,

which an excellent Menſtruum to extract the Spirit or Effluvia of Plants, as we remarkably find in ſpicy Groves Gardens, and may be uſed with good Effect.

35. But to obtain the ſaturated Tinctures of hard, reſinous, or gummy Bodies, requires a different Treatment, as in the following Experiment.

Solution of Gum Lac.

36. We took two Ounces of that hard *Indian* Roſin called *Gum Lac*, and reducing it into a fine Powder, made it into a Kind of ſtiff Paſte with Oil of Tartar *per deliquium*; we ſet this Paſte in an open Glaſs to dry by a gentle Heat; then removed it to the open Air, that it might relent or grow ſoft; and after this we dried it again as before: By repeating the Proceſs once or twice the hard Body of the Roſin was at length reſolved into a purple coloured Liquor; which being now gently dried, and reduced to Powder, afforded an excellent Tincture, by being boiled for two or three Hours in a tall Glaſs with Alcohol.

The Experiment extended.

57. This Proceſs is almoſt general, or may be advantageouſly uſed for making the Tinctures of *Myrrh*, *Gum Juniper*, *Dragons-Blood*, *Amber*, and other hard, gummy Subſtances, which will ſcarce otherwiſe yield a Tincture in Spirit of Wine. Any Improvement in the extracting Tinctures with Alcohol may tend conſiderably to improve the Art of Pharmacy; becauſe ſuch Tinctures are generally found powerful Medicines, the Spirit of Wine appearing greatly to increaſe the Virtue of the Subjects. Thus, tho' the Tincture of Amber prepared in this Manner appears to be only a bare Solution of the Subſtance of the Amber, yet it is found to have ſuch Effects as are no Way equalled by any fine Powder of Amber: And what ſeems remarkable,

able, tho' ſo large a Quantity of fixed Alkali be uſed in the Preparation of theſe Tinctures, yet they give no manifeſt Signs of containing an Alkali; which is therefore changed in the Operation, either by the Acid naturally contained in theſe reſinous and gummy Bodies, or by being expoſed to the Air, or by both.

Varied. 38. There are other Methods of extracting the Tinctures of theſe hard, gummy Bodies, but that delivered appears to be the beſt; tho' it might perhaps be ſhortened, by uſing ſome proper intermediate Subſtance to divide the Particles of the Subject, ſo as that the alkaline Salt, the Air, and the ſpirituous Menſtruum might all come into fuller contact therewith and act more forcibly thereon. And for this Purpoſe we would recommend pure virgin Earth, ſuch as is commonly uſed for the making of Teſts or Cupels; by Means whereof Spirit of Wine will extract a tolerable Tincture from *Myrrh*, without the Addition of any fixed Alkali.

39. But when Tinctures not ſpirituous, or only aqueous Solutions of theſe hard, gummy Bodies are required, we recommend the Uſe of the ſoluble Tartar, or *Tartarum Tartarizatum*; for a Solution of this Salt will readily diſſolve Myrrh, even in the Cold; as Water diſſolves Gum-Arabic *.

EXPERIMENT III.

The beſt Method of making Syrups.

40. We took three Ounces of the yellow external Rind of freſh Oranges, and infuſed them in a cloſe Veſſel, with a gentle Heat *in Balneo*

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* See *Lect.* XIII. *Exp.* V. §. 47.

Mariæ, for ſix Hours, along with a Pint and a half of pure Water; then ſuffering the Infuſion to cool we filtred the Liquor; and, adding to it twice its own Weight of hard double-refined Sugar, made it into a Syrup, in a cloſe Veſſel ſet *in Balneo Mariæ*. *Syrup of Oranges made.*

41. We could not contrive a general Example to fit all Syrups, becauſe they differ greatly in Reſpect of the Liquors of which they are made; or according as theſe Liquors are Infuſions, Decoctions, natural Juices, Wines, or Vinegars. We choſe to give an Inſtance in a Syrup made of a Liquor by the Infuſion of an aromatic Subſtance, whoſe Virtue would be almoſt intirely loſt if the Syrup were to be prepared by long Boiling, as it is ſometimes directed, with leſs than an equal Weight of Sugar. Diſpenſatory-Writers have perhaps no where erred more remarkably than in directing the Making of Syrups; which ſeems the more ſtrange, becauſe this Part of Pharmacy is extremely facile. The Misfortune ſeems to have lain here, that great Men cannot ſubmit to conſider common and ordinary Things: nevertheleſs the Credit of a Phyſician may ſink in the Eſteem of thoſe who by their Employment are led to a Knowledge of theſe ordinary Things. *Uſes.*

42. We judge that the Whole of this Buſineſs may be reduced to a few eaſy Rules, which we ſhall here endeavour to lay down for improving this Branch of Pharmacy. And (1) It is Matter of Experience that aqueous Infuſions, Decoctions, or other aqueous Liquors, require twice their own Weight of dry Sugar-Candy to make them into a Syrup of a juſt Conſiſtence for keeping, without candying or fermenting. This Rule, by directing the Uſe of *Sugar-Candy*, ſeems to fix the Conſiſtence of Syrups with Exactneſs; *Rules.*

neſs; becauſe all Salts acquire a determinate Proportion of Water in cryſtallizing; ſo that Sugar in the Form of Candy conſiſts of one certain Proportion of Water, whilſt different Kinds may hold more or leſs aqueous Matter, according to the Manner of refining, the Accidents of Weather, *&c.* Hence therefore all ſuch Infuſions for Syrups as are of a delicate or deſtructible Colour, which is impaired by boiling (for Example, Violets, Clove July-Flowers, *&c.*) and all ſuch Infuſions as contain any volatile Parts, which would evaporate by a boiling Heat, (for Example, thoſe of Nutmeg, Cinnamon, Orange-Peel, Citron-Peel, *&c.*) ſhould have twice their own Weight of Sugar added to them, and be kept cloſe covered in the gentle Heat of a *Balneum Mariæ*, till the Sugar is diſſolved; to haſten which the Sugar ſhould be firſt reduced to fine Powder.

43. (2) The Decoctions of ſuch vegetable Subſtances as loſe no valuable Parts by boiling, may be boiled down to the Form of a Syrup along with their own Weight of Sugar; the two being firſt clarified together with Whites of Eggs in the ordinary Way: But if the Ingredients here contain any unctuous or balſamic Parts on which their medicinal Virtues depend, let the Sugar be added from the firſt, and boiled along with the Ingredients; afterwards ſtraining and clarifying the Decoction, before it is boiled to near the full Conſiſtence of a Syrup. This Rule is founded upon that remarkable Property which Sugar has to diſſolve Oils, or the finer reſinous Subſtances, ſo as to make them intimately mix with Water. Whence it may deſerve to be conſidered whether the *Syrup* of *Myrtles*, *Comfrey*, and *Diacodium* ſhould not be thus prepared. It muſt alſo be obſerved that

by boiling the Sugar ſo long with the Decoction the aqueous Part exhales, and leaves the Syrup much ſtronger than it could have been made without this boiling.

44. (3) All vegetable Juices are to be thoroughly purified before they are made into Syrups. Thus the Juices of Citrons, Lemons, and Oranges are to paſs the Filtre, and then be made into Syrups, without boiling, according to the firſt Rule; obſerving to uſe no metalline Veſſel about them. But the Juices of Fruits, as particularly Mulberries, Rasberries, *&c.* will not clarify without a beginning Fermentation; but by ſtanding for a Day or two they will begin to ferment and liquify, and may then be commodiouſly ſtrained thro' Flannel; after which theſe alſo are to be made into Syrups with about an eighth Part leſs than twice their own Quantity of Sugar, or with two Pounds and twelve Ounces of Sugar to a Pint of Juice, on account of their being ſomewhat ſaccharine themſelves. And this holds alſo of Wines and Vinegars, when they come to be made into Syrups; for Wine contains an inflammable Spirit which does not incorporate with Sugar; and alſo a thick ſyrupy Subſtance, which is found in Vinegar likewiſe. By a due Application of theſe Rules we apprehend the Buſineſs of making Syrups may be brought to tolerable Perfection.

Experiment IV.

The beſt Method of making Electuaries, by an Example in the Saſſafras-Electuary.

The Saſſafras Electuary made

45. We took two Ounces of the beſt Saſſafras newly raſped, and half an Ounce of Cinnamon finely powdered; theſe Ingredients we boiled in a tall

a tall Glaſs in a Sand-Heat, with ten Ounces of Water and fourteen Ounces of Sugar, ſo as that nothing might evaporate, for two Hours; then ſtraining and preſſing out the Syrup, we added to it an Ounce of freſh raſped Saſſafras, a Dram of Cinnamon, and ten Grains of Nutmeg, both reduced to fine Powder; and made the Whole into an Electuary.

Regulation. 46. In the common Method of making this Electuary the Saſſafras and Cinnamon are boiled in the Water, whereby a great Part of their Virtue is loſt or not extracted: Whence the Medicine comes to be defrauded of its Due. But here, by boiling the Ingredients in a tall Glaſs, with a due Proportion of Sugar and Water, to make a Syrup (allowing an extraordinary Proportion of Water for what the Saſſafras will drink up) we obtain the fine aromatic Virtues of the Ingredients to Advantage, without any conſiderable Loſs.

Rules. 47. To make Electuaries in Perfection where a Syrup is employed as their Baſis, (1) the Syrup ſhould be prepared in the Manner above delivered *, ſo as that the Virtues of the Ingredients may be preſerved; (2) the Powders, or Species employed, ſhould be freſh and fine ground; (3) the Gums, where any are uſed, muſt be well cleanſed, and diſſolved in their proper Menſtruums; and (4) the Whole muſt be mixed, or thoroughly united, into a ſmooth, uniform Subſtance, of a due Conſiſtence for keeping, without either candying or running into Fermentation.

48. (1) Where Syrups are uſed in the making of Electuaries, care is not only required that the Virtues of the Ingredients of the Syrups be

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* *Exp.* III.

preſerved as much as the Form will allow of, but alſo that its Conſiſtence be not too high; for this would diſpoſe it to candy in the Electuary, and render the Medicine unduly mixed, or knotty; the Sugar concreting together in Lumps, or ſhooting away from the Species. Again; If the Syrup be made too thin or aqueous, ſo as not to ſuſpend and hold the Powders together by a binding Conſiſtence, it will of Neceſſity ferment in hot Weather, and become firſt ſomewhat vinous, afterwards ſour or acetous, and at length corruptive *a*); ſo as to change, invert, or deſtroy the Nature of the Medicine: For purgative Ingredients, by Fermenting, loſe their purgative Virtues; and all other Ingredients, by Corrupting, are reduced to an inert Kind of Fæces or *Caput mortuum*, very different from the Thing intended *b*). And hence Electuaries that have thus fermented, or changed their Nature, may ſometimes prove pernicious, inſtead of ſalutary.

49. The Electuaries made with the Pulp of Fruits are leſs diſpoſed to keep, for any conſiderable Time, perfect, on account of the greater Tendency which ſuch pulpy Subſtances have to Fermentation and Putrefaction. Thus, tho' the *Lenitive Electuary* were made ever ſo artificially, it will ſcarce keep many Months without altering its Nature; but eſpecially if the Conſiſtence was originally too thin: Whence ſuch Electuaries ſhould be made in ſmall Quantities, or freſh as they come to be wanted.

50. But this does not equally hold of the *capital Electuaries*, ſuch as *Venice-Treacle*, or *Mithridate*; which require to lie for ſome Time, that the Ingredients may digeſt, or ripen, as it were,

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a) See *Lect.* X. *paſſim.* *b*) See *Lect.* VII.

and grow mellow together; for the Gums and Spices that enter theſe Compoſitions preſerve the Medicines from Alterations for the worſe, and the Mixture becomes more perfect by Time; provided the Honey uſed in their Compoſition do not candy, or the Whole become too dry. To keep the Honey from candying, ſome Artiſts mix the Spices and Gums with it unclarified; only taking Care to ſeparate the foul Parts that lodge either at the Top or Bottom. And if the Medicines prove too dry, it is uſual at any Time to ſoften, or beat them up in a Mortar, with *Canary*: And thus theſe Capitals of the Shops are ſuppoſed to improve by keeping. But *Diaſcordium*, having few of the warm Gums in its Compoſition, is more apt to alter, and loſe of its aſtringent or ſtyptic Quality by keeping: For which Reaſon it ſeems an Alteration here for the better, to uſe a Quantity of *Saccharum roſatum* inſtead of Honey, or *Diaſcordium*; as this not only gives a greater Compactneſs to the Medicine, but alſo contributes to preſerve its Colour and Virtues.

51. (2) The Powders, or Species, that enter the Compoſition of Electuaries, ſhould be freſh, becauſe they loſe of their Virtue by keeping; and they ſhould alſo be fine ground, becauſe they would not otherwiſe intimately mix with the Honey or Syrup, nor ſo readily part with their Virtues in the Stomach, nor render the Medicine ſo agreeable to the Eye. The common Method of reducing theſe Powders to a ſufficient Degree of Fineneſs, by the Mortar and Searce, is faulty; becauſe this Method expoſes them too long to the Action of the open Air; whereby their more volatile and grateful Parts are carried off, whilſt only the groſſer are left behind: it might therefore be proper to have a cloſe

Engine contrived for the Purpoſe, ſo as to prevent this ill Effect.

52. Some Artiſts grind their Powders for Electuaries by Means of a Horſe-Mill; but the Mill-Stones here wear off, and communicate a gritty or ſtony Matter to the Ingredients, ſo as to prove diſagreeable in the Mouth, and ſomewhat increaſe the Bulk of the Medicine, without adding to its Virtues. Nor is this Method, by the Mill, free from the Inconvenience of the Mortar; for the finer or more ſpirituous Parts of the Ingredients alſo fly off; as is ſenſibly found by the whole Neighbourhood where any large Quantity of the Ingredients for *Venice-Treacle*, *&c.* is ground by the common Horſe-Mill. *Improvements.*

53. (3) The better Way doubtleſs is, by the Means of Iron Rollers, moving oppoſite to each other in a cloſe Box, to grind all the Ingredients, *viz.* the purified Gums, the Roots, Herbs, Flowers, *&c.* along with the Honey and Wine, after the Manner of the new invented *Chocolate-Engine*; for thus the fine, volatile, and aromatic Parts of the Ingredients may, as well as the groſſer, been tangled with the Honey and Gums, and all at once be mixed uniformly together into a ſmooth Maſs of a due Conſiſtence.

54. (4) But perhaps a much better, though more troubleſome, Method would be, to get out the full Virtues of the Ingredients, without any of their groſſer Parts, in the Form of Extracts, eſſential Oils, *&c.* and to mix theſe Oils, Extracts, Gums, Roſins, *&c.* together, with a ſuitable Proportion of Honey, *&c.* ſo as at once to perfect and concentrate the Medicine; which might therefore be given in Doſes of an agreeable Smallneſs, with all the Advantages that can well be expected. And the ſame Method ſeems alſo applicable to the making of *Pills* and *Troches.*

EXPERIMENT V.

The beſt Methods of making the compound Oils, Unguents, Cerates, and Plaiſters.

Oils, or Liquid Balſams. 55. We took twelve Ounces of fine Sallad-Oil, half a Pint of *Canary*-Wine, and half an Ounce of Dragons-Blood reduced to fine Powder; theſe we boiled together, over a gentle Fire, till the Wine was exhaled; and thus obtained a fine red Oil, or liquid Balſam. *Conſiſtent Balſams.* (2) To one Half of this Oil we added four Ounces of yellow Bees-Wax, ſix Ounces of *Venice* Turpentine, and diſſolved them together over the Fire; then removing the Veſſel into the Cold, we added half an Ounce of Balſam *Peru*; and thus made a red Ungent, or better Sort of *Lucatellus*'s Balſam. *Cerates.* (3) To the other Half of the red Oil we added a due Proportion of Wax; ſo as when cold to give it the Conſiſtence of a Cerate, or ſoft Plaiſter: *Plaiſters.* And (4) By adding more Wax, and a Proportion of Roſin, we made the Cerate into a Plaiſter of a hard Conſiſtence.

The Experiment extended. 56. This Experiment at once ſhews us the Method of preparing the compound Oils, Unguents, Cerates, and Plaiſters. The making of compound Oils, in general, depends upon boiling certain Ingredients, as particularly recent Herbs well bruiſed, or elſe their Juices, in Oil, till the aqueous Moiſture is exhaled (as the Wine was in the preſent Experiment) and the Plant become almoſt criſp; at which Time the Veſſel muſt be removed from the Fire, and the Oil ſqueezed from the Herb by Means of a Screw-Preſs.

And applied. 57. This Oil is now to be ſet over the Fire again, that its remaining aqueous Moiſture may exhale, and the groſſer Parts of the Whole ſubſide; whereby the Oil will become not only more beautiful in Colour, but alſo more durable, or keep the better from turning mouldy. If the Pan be not removed from the Fire before the Herb is grown criſp, the Oil will be in Danger of turning black, or being burnt; which both ſpoils the Colour, and gives a diſagreeable Odour. If theſe Cautions are duly obſerved, the common compound Oils, by Decoction, may be obtained in their intended Perfection; as Oil of Camomile, Elder, Roſes, Earth-Worms, *&c.* And after the ſame Manner are ſeveral compound Ointments made, by boiling Herbs along with Lard, or Suet; as the Ointment of Elder, Populeon, Nerve-Ointment, Melilot-Suet, *&c.*

58. The red Oil, obtained in the firſt Step of our preſent Experiment, ſhews how liquid compound Balſams are procurable by diſſolving reſinous Gums in Oil, over the Fire. And in this Manner a fine Balſam may be made with *Gum Elemi*, and tinged beautifully red with Dragons-Blood, or an Infuſion of Alkanet Root in Oil. And upon the ſame Foundation might ſeveral excellent liquid Balſams be prepared for chirurgical Uſes.

59. Powder of Red Saunders has been commonly uſed, inſtead of Dragons-Blood, in the making of *Lucatellus*'s Balſam; but doubtleſs Dragons-Blood is much better ſuited to the Intention of a Balſamic, a Healer, and Detergent; and alſo improves the Colour of the Medicine: Tho' Red Saunders may be made to give a very good red Colour to the Balſam, by infuſing the Powder cold for two or three Days in White Wine; which opens the Body thereof, exalts the Colour, and renders it communicable with Advantage to the unctuous Ingredients.

But this End may be more expeditiouſly anſwered by infuſing a little Alkanet-Root in the Oil.

60. The Conſiſtence of an Unguent is given either by uſing animal Fats, as Lard and Suet, or by the Addition of Wax, Roſin, Pitch, dry Powders, metalline *Calces*, *&c.* and by adding a ſmaller or larger Proportion of theſe ſolid or dry Ingredients, we obtain the Conſiſtence of a Cerate, or Plaiſter, reſpectively. When hard animal Fats are uſed, the Proceſs differs not from that for making the compound Oils*; and where Wax, Roſin, *&c.* are employed, the Management is the ſame as in the preſent Experiment, where the Conſiſtence of the Oil is thickened into that of a Balſam by Wax.

61. When dry Powders, or metalline *Calces*, are uſed in the making of Ointments, the Powders ſhould be freſh and fine ground, and the metalline *Calces* made more ſubtile by Triture; after which the Whole may be mixed ſmooth together, or beat up in a Mortar: And thus the *Unguentum album*, *Deſiccativum rubrum*, *Diapompholygos*, &c. are readily prepared.

62. The Plaiſters made with metalline *Calces*, ſuch as *Diachylon*, and *de Minio*, require no Wax or Roſin to give them an emplaſtic Conſiſtence; the bare Solution of the metalline *Calces*, or the Litharge, and Red Lead, by boiling in the Oil, being ſufficient for the Purpoſe. Thus, if half a Pound of Red Lead, half a Pint of Vinegar or Water, and twelve Ounces of Oil, be boiled together over a gentle Fire, with continual Stirring, till the aqueous Moiſture be conſumed, and the Red Lead entirely diſſolved; the Matter, when cold, will be of a hard, emplaſtic Conſiſtence, and differently coloured, or red,

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* See above §. 55.

brown, or black, according as it was more or leſs boiled.

63. In the making of Plaiſters with metalline Powders and Oils, it is always proper to add Water or other aqueous Liquor, to keep the Mixture from burning, or turning black, before the due Conſiſtence is gained, or the requiſite Diſſolution made. But here great Care muſt be had, not to throw in cold Water, if that added at firſt be exhaled before the Operation is finiſhed; for this would be dangerous, by cauſing the Matter to crackle, fly about, and boil over with great Violence: But if the Water be added in the State of boiling, it occaſions no Tumult; and may be thus uſed with Safety.

64. When aromatic Species, native Balſams, or eſſential Oils, are ordered in Unguents or Plaiſters, Care muſt be taken to add ſuch Ingredients towards the End of the Operation, when the Veſſel is removed from the Fire; becauſe the Heat of boiling Oil, *&c.* would cauſe the fine aromatic or odoriferous Parts of the Ingredients to exhale, and be loſt to the Unguent or Plaiſter. The ſame Caution ſhould be likewiſe extended to the *Cantharides* uſed in the *Paſta epiſpaſtica*, &c. and to other Bodies of a delicate Texture, whoſe more efficacious Parts are exhaled by Heat. And by the due Obſervation of theſe few Rules and Cautions, the common compound Oils, Unguents, Cerates, and Plaiſters, may be made in conſiderable Perfection.

AXIOMS *and* CANONS.

1. We learn from the preceding Enquiry, That ſome Part of the Salts of Plants, as well as their Oils, will riſe by Diſtillation with Water, and give an acid or alkaline Nature to the

ſimple Waters thus prepared, according to the Nature of the Plant *a*).

2. That no Simple Waters ſhould be diſtilled ſo low, as to bring over any remarkable acid or alkaline Liquor from the Plant; for fear of miſchievous Effects, or making ſuch Waters prove emetic or purgative, contrary to the Intention *b*).

3. That the Virtues of Simple Waters chiefly depend upon their containing the eſſential Oil of the Plant *c*).

4. That there are two Methods of perfecting Simple Waters; *viz.* Cohobation, and Fermentation *d*).

5. That all Tinctures and Infuſions of Ingredients, whoſe principal Virtues depend upon their lighter, or more ſubtile and ſpirituous, Parts, ſhould not be made with Heat, but in the Cold *e*).

6. That if ſuch Tinctures or Infuſions be required rich and ſtrong, they are to be made ſo, not by ſuffering the Menſtruum to remain long upon the Ingredients, or by the Uſe of Heat; but by adding freſh Ingredients ſeveral Times to the ſame Liquor; infuſing them quick, and each Time keeping out the Ingredients that have once been uſed *f*).

7. That the Fire is apt to exhale, alter, or conſume the more ſubtile and ſpirituous Parts of Vegetables; and therefore unfit to be uſed where theſe more delicate Parts are required *g*).

8. That the Buſineſs of Infuſions and Tinctures may be greatly improved by extracting the efficacious, or more ſpirituous Parts of Vegetables, unaltered in their Nature; yet con-

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a) *Exp.* I. *b*) ib. *c*) ib. *d*) ib. *e*) *Exp.* II. *f*) ib. *g*) ib.

centrated, or brought together into a moderate compaſs.

9. That rich Tinctures may be extracted, with Spirit of Wine, from the hardeſt reſinous and gummy Bodies hitherto known, by Means of fixed Alkali properly applied *a*).

10. That even aqueous Solutions may be made of the ſame Kind of Bodies, by Means of the *Tartarum tartarizatum*, or ſoluble Tartar *b*).

11. That the Ways in common Uſe for the making of Syrups, Electuaries, compound Oils, and Plaiſters, are improveable by the Obſervance of a few eaſy Rules *c*).

12. That, therefore, there are grounds to expect ſome Improvement of the common Pharmacy, upon the footing it now ſtands, barely by perfecting the Methods of preparing the Shop-Medicines in Uſe, without either retrenching their Number, or introducing new ones; that is, by reducing the Art to a greater Simplicity.

a) *Exp.* II. *b*) ib. *c*) *Exp.* III. IV. V.

LECTURE XVI.

CONTAINING

Attempts for reducing PHARMACY *to a greater degree of Simplicity and Efficacy.*

The Subject. WE now proceed to conſider how Pharmacy may be reduced to Simplicity; which in Arts appears to include Perfection.

The Simplicity of Pharmacy. 2. The Simplicity of Pharmacy ſeems to conſiſt in ſupplying a few powerful, parable, ſafe, and agreeable Medicines, for the Cure of Diſeaſes.

The Fate of Medicines. 3. Thoſe verſed in the Hiſtory of Phyſic obſerve that Remedies have their Run, or Revolutions of Fate and Fortune; many of them being highly eſteemed or magnified for a Seaſon, and afterwards thrown aſide and neglected.

4. Not to mention the Medicines celebrated by the Ancients, there are Numbers of others which have had their Revolutions almoſt within our own Memory. The *Elixir Proprietatis* of *Paracelſus*, the *Liquid Laudanum* of *Helmont*, the *Sal volatile oleoſum* of *Sylvius*, the *Aperitive Tincture* of *Mœbius* *, the *Antihectic* of *Poterius*, the *Aqua benedicta*, or *Vinum emeticum*, of *Rulandus*, the *Bezoardic Powder* of *Sennertus*, Ceruſe of Antimony, and many more, have been extrava-

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* That is, Spirit of common Salt neutralized with Salt of Tartar, and tinged with Red Roſes.

gantly valued in their Time; but are now ſunk in the Eſteem of Phyſicians. And thus perhaps our preſent Opiates, our Salt of Vipers, our Pearls, our Bezoar, our *Aurum fulminans*, &c. may loſe their Credit hereafter, or give Way to others of no greater Efficacy.

Cauſe of their Fate.

5. If we enquire into the Cauſe of this Inſtability in Pharmacy, it does not appear owing to the Medicines themſelves, but rather to the Inattention, Levity, and Raſhneſs of Men: Inattention, in not ſufficiently regarding and diſtinguiſhing between the Kinds and Differences of Diſtempers and Conſtitutions; Levity, in preſently changing one Medicine for another, if the expected Effect is not ſoon procured; and Raſhneſs, in uſing ſuch Medicines as come recommended by incompetent Judges, or unfair Repreſenters.

6. If the Cauſe were owing to any Changes in the Medicines themſelves, we could have little Hopes of redreſſing the Evil; but as it is owing to ourſelves, we are hence encouraged to look out for a Remedy.

Regulation.

7. The Art of forming a ſound Judgment of the Succeſs and Virtues of Medicines is ſo little known, that the Mind uſually fluctuates therein, as being deſtitute of a ſecure Foundation; and conſequently is led by Rumour, Opinion, and Example, inſtead of the true Light ariſing from careful Obſervation, and well digeſted Experience. Whence it frequently happens that unlucky Events are attributed to uſeful Medicines; whilſt ſuch Events were really owing to ſome other Cauſe.

8. This Inattention is ſucceeded by Levity and Raſhneſs: For when a Medicine thus fails to anſwer the Expectation conceived of it, it is uſual to reject it with Contempt, and immediately to

ſeize, in its Stead, the firſt new one that comes ſtrongly and vehemently recommended; which again, after Trial, is frequently rejected in the ſame Manner as the former. And thus the Lives of Phyſicians are often ſpent in flying from one Medicine to another, without fixing upon thoſe that are ſtable, or ſuch whoſe Virtues are duly determined and aſcertained.

9. This perverſe Temper or ill Habit of the Mind muſt therefore be cured; or elſe Phyſicians will continue to fluctuate, and never bring Pharmacy to a State of Perfection.

10. The Way of rectifying this ill Habit, we apprehend, is to acquire a Competency of ſound and fundamental medicinal Knowledge, by keeping ſteady to the Uſe of a few ſimple Medicines; which are eaſily prepared, no way hazardous, and yet powerful in their Effects: And to ſhew the Way of procuring a few ſuch Medicines, is the Deſign of our preſent Lecture.

11. We judge that all Medicines are commodiouſly reducible to four general Claſſes; *viz.* *Evacuants*, *Alterants*, *Strengtheners*, and *Quieters*: For as all the Cauſes of Diſeaſes muſt regard either *Quantity*, *Quality*, or *Motion*, the Medicines adapted to theſe Cauſes will be either *Evacuants*, *Alterants*, *Augmenters*, or *Appeaſers* of Motion in the Body.

12. It muſt, however, be obſerved, that under each of theſe general Tribes of Medicines there are ſome better adapted than others to the Diſeaſes of particular Parts. Thus it is Matter of Obſervation, that Mercury particularly affects the ſalival Glands, Cantharides the Bladder, *&c.* all which Remedies are to be collected, as ſo many particular Inſtances, under our reſpective general Heads of Medicines. And by duly proceeding in this Manner, it ſhould ſeem that

we might eaſily fix upon a ſmall Collection of Remedies, able, with a proper Regimen, to cure the ordinary Diſeaſes.

13. At leaſt, by throwing out of our preſent Collection ſuch as are certainly found to be of ſmall Efficacy, or certainly dangerous, we might greatly retrench the preſent Set of *Officinals*, and bring the more ſerviceable of them within the Compaſs of a *portable Cheſt*. And with this View we ſhall endeavour to point out ſome of the more efficacious, parable, ſafe, and agreeable Evacuants, Alterants, Strengtheners, and Quieters; all along fixing a Mark upon thoſe which we take to be either unſafe or inſignificant.

14. Our firſt Experiment will ſhew a Method of procuring a ſafe Emetic; the ſecond will ſhew how to prepare a ſafe Purgative; the third how to prepare a ſafe Perſpirative; the fourth how to prepare a ſafe Alterant; the fifth how to prepare an innocent Strengthener; and the ſixth how to obtain a powerful Quieter, or Anodyne.

EXPERIMENT I.

An eaſy and ſimple Method of obtaining a ſafe and gentle Emetic.

15. Two Drams of the common white Ipecacuanha being reduced to fine Powder, and infuſed for two or three Days in half a Pint of white *Liſbon* Wine, in the Cold; if the clear Liquor be decanted, freſh Wine may be added to the remaining Powder, ſo as to extract all the Virtue, which it will thus yield to Wine in the Cold. *An Emetic prepared.*

16. This Infuſion of Ipecacuanha in Wine appears to be the moſt ſafe, gentle, and agreeable Emetic hitherto known: Whence it may in moſt Caſes be properly ſubſtituted for the *Vinum benedictum* *Uſes.*

dictum, the *Tartarum emeticum*, and the other antimonial Emetics; which are all attended with ſome Degree of Virulency and Uncertainty in their Operation.

Ipecacuanha analyſed 17. The Ipecacuanha Root, upon a proper Analyſis by Means of Water and Spirit of Wine, is found to contain a direct ſaline and reſinous Part, whereof the ſaline is the larger; whence even an aqueous Infuſion of the Root will largely extract its Virtues: So that a ſtrong White Wine ſeems a Menſtruum well adapted to the Extraction both of its ſaline and reſinous Parts, on account of the large Proportion of Water, and a leſs of inflammable Spirit, that it contains. Add to this, that Emetics, as well as Purgatives, are found to act the freer, eaſier, and quicker, when joined with Wine, or other ſtrengthening ſpirituous Vehicle. However, after both Water and Spirit of Wine have ſucceſſively acted upon this Powder, it ſtill retains ſome Virtue; ſo that its Power is greateſt when given in Subſtance: Whence our preſent Method of extracting a Tincture from it with Wine only abates its Violence, and, in ſome Meaſure, moderates its Operation; ſo as to fit it for weak Conſtitutions, or render it almoſt univerſally ſafe.

Not improved by Chemiſtry. 18. This Root may, therefore, paſs for one of thoſe Simples which are little or nothing improved by a chemical Treatment; Nature ſupplying it almoſt ready prepared to our Hands, ſo as to require no more than drying and Reduction to Powder, at moſt no more than a bare Infuſion in Wine, to render it a ſafe Emetic.

Farther Uſes. 19. Now, being once poſſeſſed of ſuch an Emetic as this, which ſeems to include the Excellencies of all thoſe of the ſame Tribe, it is doubtleſs proper to practiſe the *Method of Rejection*

tion upon the reſt; or at leaſt to examine whether any of them deſerve to be retained and kept in the Shops.

Poiſonous Emetics.

20. We obſerved above *, that the common antimonial Emetics, of which there is a great Variety, are virulent, or in ſome Degree poiſonous; and therefore not to be truſted, when ſafer can be procured to anſwer the End. 'Tis true, ſome Practitioners have ventured to give Arſenic itſelf, in the Quantity of a few Grains, as an Emetic; and thus it ſometimes operates violently, after the Manner of the emetic Preparations of Antimony, which are nearly allied thereto. But as we certainly know, by many fatal Inſtances, that Arſenic is a virulent Poiſon, even in a ſmall Doſe; it may ſeem a Kind of Madneſs to uſe it as an Emetic, when Ipecacuanha is at Hand. And the ſame is to be underſtood, tho' in a leſs Degree, of the *Mercurius Vitæ*, Glaſs of Antimony, Antimonial Cups, the Perpetual Pills, the Sulphurs of Antimony, and indeed all other draſtic Emetics; which have a direct virulent Virtue, and, if given in too large a Doſe, produce poiſonous Effects. And here we do not except *emetic Tartar* itſelf; which, unleſs prudently diluted with Wine or ſome Cordial Water, is apt to prove not only uncertain and churliſh in its Operation, but ſometimes virulent or poiſonous; eſpecially when exhibited in a dry Form, as in that of Pills, Powder, or Bolus: For all antimonial or other metalline Emetics, coming in a dry Form into the Stomach, ſeem to lodge in its membranous Coats, and ſtimulate and corrode them; ſo as to occaſion Spaſms, Convulſions, *&c.* after the Manner of Poiſons.

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* §. 16.

Regulation.

21. And tho' Solutions of Vitriol, Verdigreaſe, and various Preparations of Copper, have been, and ſtill continue to be, uſed as Emetics, and generally operate quick; yet we cannot judge ſuch Preparations ſafe, or any way comparable to Ipecacuanha for Safety. And even theſe cupreous Emetics, when given in a large Doſe, have a corroſive Effect upon the membranous Parts of the Stomach; ſo as to prove, in a leſs Degree, poiſonous. And thus, if the whole Tribe of Emetics were carefully examined, and their Effects noted from competent Experience, we judge they would moſt of them be found unſafe or dangerous; and conſequently deſerve to be baniſhed the Shops, as Emetics, whilſt their Place may be ſo well ſupplied by Ipecacuanha. And this Method of Examination and Rejection being duly practiſed, might, as we apprehend, thin our Shops, and reduce the Bulk of our Pharmacopœias, to the great Advantage of Pharmacy and Medicine.

EXPERIMENT II.

An eaſy Method of procuring a ſafe and effectual Purgative.

A Cathartic prepared.

22. If in a Quart of *Dulwich*-Water we diſſolve an Ounce of fine Manna, and half an Ounce of black Tamarinds, then ſtrain off the Liquor clear, we ſhall obtain an agreeable purging Ptiſan, or cathartic Liquor, in a Doſe ſufficient for a full-grown Perſon of an ordinary Conſtitution; the Whole being drank at ſeveral Draughts, in the Space of about an Hour and half, or two Hours.

23. It appears to be Matter of Obſervation, that the common purging mineral Waters operate

with more Eaſe, Gentleneſs, and Safety, than almoſt any Cathartics of the Shops; and only require to be concentrated by boiling, or quickened, in ſome Caſes, to prevent the Trouble of taking two or three Quarts for a Doſe. Our preſent Experiment, therefore, ſhews the Method of quickening theſe Waters, by the Addition of innocent Purgatives; ſuch as are *Manna*, *Tamarinds*, *Epſom-Salt*, *Tartarum tartarizatum*, *Tartarum vitriolatum*, &c.

The mild Cathartic preferred.

24. The Shops and common Diſpenſatories abound with purgative Medicines, many of them draſtic, or violent, and ſome of them virulent, or almoſt poiſonous; of which Kinds we reckon *Roſin of Jalap*, *Elaterium*, *Scammony*, *Gamboge*, *Coloquintida*, *Aſarum*, &c. all which are of a cauſtic Nature, when given crude and alone, ſo as to prove mortal in a large Doſe: Whence we apprehend that the crude and ſeparate Uſe of all ſuch Purgatives ſhould be baniſhed; eſpecially as there are numerous Inſtances of their deleterious and poiſonous Effects, and as we are abundantly provided of ſafer and more gentle Kinds; for Example, *Rhubarb*, *Manna*, *Tamarinds*, *Caſſia*, *Cremor Tartari*, *Epſom-Salt*; and particularly the purging *mineral Waters*. Or if the Uſe of the more violent purging Simples be ſtill retained, let them at leaſt be boiled in Water; which is a certain way of rendering them milder, and diſcharging a great Part of their Malignity. And for the purgative Roſins, particularly thoſe of Jalap and Scammony, we would recommend them to be ground fine, and beat into a Paſte, with twice or thrice their Quantity of blanched Almonds; which, by their oily Matter, diſſolve the Texture of theſe Roſins, and render them more ſafe and innocent *.

The violent to be rejected.

Or rendered milder.

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* See below *Exp.* III.

25. But we do not apprehend that the Art of Medicine has any Occaſion for thoſe violent Purgatives. Certainly violent Purgatives are ſeldom proper, and generally prejudicial. If the ſtronger be ever required, we would, inſtead of the former virulent Kind, recommend the ſimple Powder of Jalap-Root; which is found to operate much more mildly, and with greater Certainty and Effect, than its Roſin, Tincture, or other chemical Preparations of the Root; which is alſo the Caſe of *Mechoacan* and *Rhubarb.*

26. We deſire it may be remembered, that the deleterious or poiſonous Nature of the violent Purgatives above mentioned is much greater in the Body than that of the poiſonous Emetics; doubtleſs becauſe ſome Part of theſe Emetics is ſoon thrown up again by the Stomach; whereas the Purgatives deſcend to the Inteſtines, and mix with the Juices of the Body: Whence we have a ſtronger Reaſon for rejecting the Uſe of theſe virulent Purgatives, than the Uſe of the virulent Emetics.

Regulation. 27. And thus we conceive the Matter of Purgatives may be reduced to a tolerable Degree of Simplicity; yet ſo as to leave Variety enough for ſuiting the different Diſeaſes and Conſtitutions where Purging is required. The Nature of our Deſign will only permit us to indicate, as we go along, the Heads of this general Enquiry into the Means of reducing Pharmacy to an elegant and uſeful Simplicity; the Introduction whereof is not to be expected from private Hands.

EXPERIMENT III.

A facile and ſimple Method of preparing a ſafe and effectual Sudorific.

28. If an Ounce of refined Camphire be beat, and ground, in a Marble Mortar, with two Ounces of blanched Almonds; the Camphire will be thus ſubtilly divided, and brought into an uniform Maſs, fit for the forming of Pills, Boluſes, *&c.* ſo as to be commodiouſly taken in the Way of a Sudorific, Diſcutient, or Perſpirative Remedy; the Doſe whereof may be aſſigned betwixt the Limits of three Grains and forty. *A Sudorific prepared.*

29. Sudorific, Perſpirative, and Alexipharmic Medicines, make a large Part of the common Diſpenſatories: We judge that their Places may be advantageouſly ſupplied by a few powerful ones of approved Virtues; among which we eſteem this of Camphire as a principal one, or at leaſt ſuperior to *Gaſcoign*'s Powder, *Lapis Contrayervæ*, *Bezoar*, &c. whoſe Virtues at beſt appear to be ſmall. *Uſes.*

30. We are ſenſible that the Qualities of Camphire are not univerſally agreed on by Phyſicians; ſome eſteeming it hot, and others cold; ſome of great, and others of little Efficacy. However, the Caſe is not to be decided by Authorities, but Experience; which ſeems to declare that Camphire is one of the moſt powerful, moſt immediate, and moſt innocent Perſpiratives, Sudorifics and Alexipharmics hitherto known: For a large Doſe of it, ſuppoſe a Scruple or more, being diſſolved in Spirit of Wine, and given to a healthy Perſon, does not increaſe the Pulſe, or excite a præternatural Heat; but rather cauſes a remarkable

Coolneſs and Compoſure, with a gentle Sweating, or Increaſe of Perſpiration. So little have the Virtues of this Medicine been underſtood; or ſo little can the Virtues of Medicines be deduced from their apparent Properties, or from reaſoning a *priori*!

31. The natural and medicinal Hiſtory of this Drug well deſerves to be traced: It appears to be an eſſential Oil, of peculiar Properties; tho' ſome would have it a Roſin, and others a Gum. Certainly it ſtands alone, as a Thing *ſui generis*; or a Body wherein the Nature of Roſins, Gums, and eſſential Oils, all meet in ſome Degree. It is perhaps one of the moſt diſcutient and ſubtile Remedies hitherto diſcovered: Whence it proves highly anodyne, perſpirative, and preſervatory. And we judge, from certain Obſervations and Experiments, that if the full Virtues of this Concrete, both internal and external, were ſufficiently known, it might ſupply the Place of numerous other Drugs and Preparations, to the Eaſe and Advantage of Pharmacy.

Farther Uſes.

32. In particular, we would recommend this Medicine to be uſed inſtead of the common ſudorific Decoctions of the Woods, in Caſes both of the recent and inveterate *Lues Venerea*: It may alſo be advantageouſly mixed along with the Balſams, or fine Turpentines, commonly uſed at the cloſe of that Diſtemper. In ſhort, we recommend it in all inflammatory, putrid, peſtilential, and even maniacal, Diſeaſes. And whoever has the Secret of prudently joining this ſimple Medicine along with Nitre, may, as we apprehend, perform Cures ſcarce to be expected from other Medicines frequently uſed for the ſame Purpoſes.

EXPERIMENT IV.

An eaſy and ſimple Method of procuring a ſafe and powerful Alterant.

33. If an Ounce of well purified Nitre, and two Scruples of Cochineal in Powder, be boiled in five or ſix Ounces of Water; and the Solution be filtred, and afterwards evaporated to Drineſs, keeping the Matter ſtirring as it thickens; a fine red or purple Powder will be left behind; that is, the Nitre will be thus diſguiſed, and reduced to a Form fit for taking in the Way of Bolus, Powder, or Solution, with any convenient Vehicle. *An Alterant from Nitre.*

34. Nitre thus prepared, in order to conceal ſo common a Thing, we judge to be an extremely ſafe and uſeful Alterant, capable of producing conſiderable Effects in the Body, without cauſing any diſturbance, or ſenſible Evacuation, unleſs in the Way of a Diuretic; in which Reſpect it operates as an Evacuant. *Uſes.*

35. It is remarkable of Nitre, that it may with Safety be injected into the Blood. *Malpighi* injected ſix Ounces of its Solution into the Jugular Vein of a Dog, without obſerving any other Effect than its proving diuretic. It is farther obſervable of it that it heightens the florid Colour of extravaſated Blood, and excellently preſerves it from Putrefaction; yet does not liquify freſh and warm Blood, as has been imagined, but ſomewhat thickens it, almoſt in the Manner of a Mucilage: Which may give us the phyſical Reaſon of many of its Effects in the Body; as particularly its allaying Inflammations and Fevers, its ſtopping Hæmorrhages, curing the Spitting of Blood, *&c.* *Virtues.*

36 If the medicinal Virtues of this ſimple Medicine were to be enumerated, as they ſtand confirmed by competent Experience, perhaps they would prove more numerous than thoſe of almoſt any Medicine hitherto known. It has been found ſerviceable in the Stone, and Stoppages of Urine; in Deliriums, in malignant Fevers, in Diarrhoeas attending the confluent Small Pox, *&c.* ſo as to prove a Kind of general Remedy. And as all theſe Excellencies of the Medicine are joined with that deſirable Property of being innocent, or ſcarce any Way prejudicial to the Body; it may ſeem ſtrange that it ſhould be ſo little uſed, or that Medicines no Way comparable to it ſhould be preferred before it.

Whence diſeſteemed 37. Poſſibly the mixing of Nitre with other Medicines may have occaſioned its Virtues to be leſs known, or obſerved; perhaps that Humour of changing Medicines, almoſt every Day, may not have given it the Opportunity of ſhewing itſelf; but chiefly that ſtrange Method of jumbling many Simples together in one Medicine, ſeems to have prevented the due noting of the Effects of this and other ſimple Remedies. We, therefore, wiſh that the *Medicinal Hiſtory of Nitre* were drawn up, with Care and Judgment; as being perſuaded, that both Pharmacy and Medicine might, by means thereof, be brought much nearer to Simplicity and Perfection than they are at preſent.

EXPERIMENT V.

An artificial Method of preparing a powerful and innocent Strengthener.

38 We put half a Pound of the beſt *Peruvian* Bark, reduced to fine Powder, into a proper Glaſs, and poured upon it two Quarts of Spirit

of Wine; then ſhaking them well together, ſet them to digeſt in a Sand-heat for two or three Days, till the Spirit of Wine appeared of a deep red Colour, inclining to Purple. We now ſtrained the Tincture through a cloſe Linen, and committed the Fæces at laſt to the Preſs. Then returning the Preſſings, or remaining Powder, into the ſame Glaſs, we poured thereto two Quarts of ſtrong White Wine, and again ſet the Matter to digeſt for two or three Days; then ſtrained as before. After this we put the two Liquors into a Glaſs-Body, and diſtilled off a large Part of the Spirit of Wine; then evaporated the Remainder in a glazed Veſſel, taking Care to keep the Matter ſtirring, and waſhing down, with ſome of the Spirit of Wine, the reſinous Parts that adhered to the Sides of the Veſſel. When the Matter began to grow thick, we added to it three Ounces of the Syrup of Orange-Peel; and thus brought the Whole to the Conſiſtence of an Extract.

An eſſential Extract of the Bark.

Its Hiſtory

39. This Method of extracting the Virtues of the Bark is the Invention of M. *Charas*; who experienced its Succeſs in a large Practice for fifteen Years, wherein he never found it fail him, for the Cure of all Sorts of Intermittents. We have ourſelves alſo had a competent Experience of its Succeſs; and found it anſwer better than any other Preparation of the Bark we have ſeen: Whence we judge it the beſt Manner hitherto known of preparing an Extract from the Bark, ſo as to render it more innocent and effectual.

Rationale.

40. The Proceſs was formed upon this Suppoſition, That the Bark contained a Roſin and a Salt for its principal component Parts; to the Extraction whereof the two Menſtruums are well adapted. And, in Effect, we find that Spirit of Wine does extract a Kind of Roſin from the

Bark; and Wine ſuch a Part as renders it able to cure ſome Kinds of Intermittents in certain Conſtitutions: Whence theſe two Menſtruums, doubtleſs, take up the more medicinal Parts of this Subſtance, leaving its more woody or fibrous Part behind; which probably occaſions that Stoppage and troubleſome Weight at the Stomach we often hear complained of after taking large Quantities of the Bark in Subſtance.

41. The two finer and more medicinal Parts of the Bark being thus extracted, they are commodiouſly joined together again by the Interpoſition of the Sugar contained in the Syrup; ſo as to form an elegant Whole, that may be aromatized at Pleaſure with the eſſential Oil of Mint, Cinnamon, or Cloves.

Regimen. 42. The Doſe, and Method of exhibiting this Preparation of the Bark, are the ſame as the common; and though a much larger Doſe ſhould be given, it has not been found to produce any ill Effect. The Uſe of this Medicine is alſo attended with a quicker Recovery of the natural Complexion, Vigour, and Freſhneſs, than the Uſe of the crude Bark. And as the Medicine appears to be thus rendered ſo powerful and innocent, perhaps it may be proper to try it alſo in ſome other weakening Diſtempers, beſides Intermitting Fevers.

Elæoſaccharums recommended. 43. There are many other powerful and innocent Strengtheners, beſides this Preparation of the Bark; among the principal whereof come the capital Aromatics, Cinnamon, Cloves, Nutmeg; or rather their eſſential Oils; which being made into *Elæoſaccharums*, afford as potent Cordial Medicines, in a commodious Form, as can well be expected. But if more compounded Medicines are required, we would recommend the Uſe of a *compound Elæoſaccharum*, conſiſting of a few ſelect aromatic Oils, and the richeſt Gums and Balſams, as one general Cordial, or compound Strengthener. And thus a Medicine might be eaſily contrived, that ſhould collect in itſelf, or concentrate, the Cordial Virtues diſperſed in ſeveral capital Ingredients. Thus for Example, Camphire, Balſam *Peru*, Balm of *Gilead*, the eſſential Oils of Cinnamon, *Lignum Aloes*, Myrrh, *&c.* are all homogeneous, and capable of being united either alone, or with Spirit of Wine, or Sugar; ſo as to be given with all deſirable Advantage and Convenience.

EXPERIMENT VI.

A ready Method of procuring a ſafe Quieter, or Anodyne.

44. We took half an Ounce of Opium, and diſſolved it with a gentle Heat in five or ſix times its own Quantity of fair Water; then ſtraining the Solution, and exhaling away the ſuperfluous Moiſture, in a temperate Sand-heat, we reduced the Matter to a dry Subſtance; which being ground in a Glaſs-Mortar, with twice its own Weight of hard Loaf-Sugar, ſeems to afford us one of the beſt or mildeſt Preparations of Opium; and may be given from one Grain to three or four for a Doſe. *Opium prepared.*

45. By diſſolving the Opium in Water, we get rid of its more groſs and reſinous Parts, which are found much more pernicious than the reſt; and by dividing its Parts afterwards, with Sugar, we render the Medicine more uniform, reſoluble, and miſcible with the animal Fluids; and can thus the better adjuſt its Doſe. But ſtill this Medicine is not without ſome pernicious Property; nor is there any way known *Uſes.*

known to render the Uſe of Opium perfectly ſafe and innocent in all Conſtitutions: For if a large Doſe of it be given, it is apt to diſturb or cloud the Head, cauſe a Vertigo, Delirium, or Convulſions; in particular, it proves prejudicial to the Stomach and Inteſtines, which it is apt to inflame and ſphacelate; thus acting, in ſome Degree, as a Poiſon: Whence a better Method of correcting it ſhould be endeavoured after, or a more innocent Remedy be uſed in its Stead. A Mixture of Nitre and Camphire, we apprehend, may ſupply its Place on many Occaſions, without any Fear of Danger or Inconvenience.

Regulation of Pharmacy.

46. Thus we have endeavoured to give an Inſtance of a ſimple and ſafe Preparation in each of the four general Tribes under which we conceive all Medicines may be commodiouſly ranged; *viz.* Evacuants, Alterants, Strengtheners, and Quieters. If the Method we have here obſerved were purſued to its due Length, it might, doubtleſs, terminate in the certain Diſcovery of a few ſimple, elegant, innocent, and powerful Remedies; at leaſt it would enable us to throw out, as dangerous, noxious, or poiſonous, a large Part of our preſent *Materia medica*, and pharmaceutical Preparations; and a conſiderable Part thereof, as almoſt uſeleſs, or inſignificant: Whence ſome tolerable Degree of Perfection in Pharmacy might be obtained.

47. Thus all the Medicines that have Lead in their Compoſition are ſcarce to be truſted for internal Uſe. We have various Inſtances of the poiſonous Nature of this Metal; as particularly among the Workmen at the White-Lead Houſes, the Colourmen, or Grinders of Ceruſe, and thoſe who any way work in Lead. And it were ſufficient to baniſh the frequent internal Uſe of

Saccharum Saturni, the *Tinctura antiphtheſica*, &c. to read, in the *Miſcellanea curioſa* *, how many Men were poiſoned by drinking acid Wine rendered ſweet with Litharge.

48. But Metals do not act in the Body till they are once diſſolved: Whence crude Mercury, ſwallowed in large Quantities, proves harmleſs, through the Want of a Menſtruum in the Stomach, *&c.* to diſſolve it. But when crude Mercury is diſſolved by its proper Menſtruum, as in the Preparation of Mercury-Sublimate, we ſee it becomes one of the ſtrongeſt Poiſons. Lead, Iron, and Copper, being much more eaſily diſſolved than Quickſilver, are ſeldom taken without ſome remarkable Effect; which muſt neceſſarily prove the greater, the more of an acid, or, in the Caſe of Copper, even alkaline Humour, is lodged in the Stomach or Inteſtines: Whence we derive a phyſical Reaſon why theſe Metals often produce different Effects in different Conſtitutions. The internal Uſe of the *Cryſtals* of *Silver*, though ſometimes ſucceſsfully given in dropſical Caſes, ſhould hardly be truſted, on account of their corroſive Acrimony; which has ſometimes occaſioned bloody Stools, and extreme Weakneſs. The common Tinctures of Copper, and Solutions of blue Vitriol, can ſcarce be taken internally with Safety; as being not only emetic, but in ſome Degree corroſive and poiſonous. Even the *Aurum fulminans*, though highly eſteemed by ſome as an internal Medicine, cannot be ſafely given, unleſs it has been firſt well waſhed from its Salts, and does not meet with a ſuitable acid Solvent in the Stomach: For in both theſe Caſes it may have dire Effects; of which there have

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* Decad. III. Obſ. 30.

been remarkable Inſtances. Iron and Tin have not been found ſo pernicious to the Body, but rather beneficial; eſpecially Iron, when prudently prepared and uſed. Indeed, of all the Metals, Iron ſeems to be the moſt innocent, and ſufficiently powerful, tho' diſſolved in ſo weak a Menſtruum as Wine. And as this is the Reſult of our Method of Rejection applied to Metals and metalline Preparations, ſo we apprehend that if the ſame Method were applied to the whole *Materia medica*, there would thence reſult the diſcovery of ſafe and powerful Medicines for the Cure of all ordinary Diſeaſes: Whence we would recommend this Kind of Procedure to thoſe who regard the Improvement of Pharmacy and Phyſic.

AXIOMS and CANONS.

1. We learn from the preceding Enquiry, That certain Simples are naturally better prepared for medicinal Uſe, than by the common chemical Treatment; ſuch in particular are Ipecacuanha, Jalap, Rhubarb, Mechoacan, *&c.* Tables, or Catalogues, of which Kind of Simples ought to be formed, in order to abridge and perfect Pharmacy *a)*.

2. That moſt of the Emetics in common Uſe, eſpecially the antimonial Kind, are virulent and ſomewhat poiſonous, compared to that milder one of Ipecacuanha *b.)*

3. That many of the common violent Purgatives are of an actually poiſonous Nature, and therefore ſhould be artificially corrected, or elſe make room for more innocent Kinds to be uſed in their Stead; particularly the purging *mineral Waters*, Manna, Rhubarb, *&c.*

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a) Exp. I. *b) Exp.* II.

4. That the more violent and poiſonous Purgatives, ſuch as Elaterium, Coloquintida, Scammony, Hellebore, *&c.* may have their poiſonous Quality mitigated, or taken away, by boiling in Water and other Expedients *a*).

5. That the Effects of the poiſonous Purgatives are conſiderably greater in the Body than the Effects of the poiſonous Emetics *b*).

6. That the two principal Tribes of Evacuants, *viz.* Purgatives and Emetics, are reducible to a few ſimple and eaſy Preparations *c*).

7. That Camphire has conſiderable Virtues, as a Perſpirative, Sudorific, and Reſolver; being capable of uniting with oily Subſtances, and bearing a Relation to eſſential Oils, Roſins, Gums, and Balſams *d*).

8. That purified Nitre has many medicinal Virtues; ſo as advantageouſly to ſupply the Place of numerous other Medicines *e*).

9. That this purified Nitre has a great Power of preſerving the Blood uncorrupted, freſh, and florid *f*).

10. That many of the medicinal Virtues of Nitre do not depend upon its liquifying, but rather upon its jellying the Blood *g*).

11. That the Perfection of Phyſic and Pharmacy may have a conſiderable Dependence upon the medicinal Hiſtory of Nitre *h*).

12. That the *Peruvian* Bark may be rendered more innocent and effectual than when given in Subſtance, for the Cure of Intermittents, *&c.* by Means of a proper Treatment, or by extracting and uniting its ſaline and reſinous Parts with a ſuitable intermediate Subſtance *i*).

13. That this Bark appears to contain three very different Parts in a looſe Texture; *viz.* a roſin, a ſalt, and a woody Subſtance *k*).

a) *Exp.* II. *b*) ib. *c*) *Exp.* I. III. *d*) *Exp.* III. *e*) *Exp.* IV. *f*) ib. *g*) ib. *h*) ib. *i*) *Exp.* V. *k*) ib.

14. That poſſibly the reſinous and ſaline Extracts of the Bark may be ſerviceable in curing more Diſeaſes beſides Intermitting Fevers; and that probably the frequent Failure of the common Infuſions and Extracts of this Drug are owing to their containing much of its reſinous Part without the ſaline one, or the ſaline Part without much of the reſinous; and not a due Mixture and full Proportion of the two, as they are naturally found in the Bark itſelf: Whence the Subſtance has generally proved more effectual than any of thoſe imperfect Extracts, Tinctures, or Infuſions *a*).

15. That powerful Strengtheners, or Cordials, are obtainable from a Mixture of the richeſt Balſams, and eſſential vegetable Oils *b*).

16. That Opium may be ſo prepared as to become more innocent than in the common Methods of treating it *c*).

17. That a leſs noxious Quieter is wanted than Opium, and may, in ſome Meaſure, be ſupplied by Nitre and Camphire *d*).

18. That no Preparation of Lead can be long or freely uſed internally, without conſiderable Hazard *e*).

19. That the common Solutions and Preparations of Copper, Silver, Gold, and Mercury, are hardly proper for internal Uſe; nor even Tin and Iron, unleſs prudently prepared with gentle Menſtruums, and cautiouſly given *f*).

20. That there are rational Grounds to expect ſome conſiderable Improvements in the preſent State of Pharmacy and Medicine, by a due Enquiry, and a proper Uſe of the Means conducive to this End *g*).

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a) *Exp.* V. *b*) ib. *c*) *Exp.* VI. *d*) ib. *e*) ib. *f*) ib. *g*) See the whole Lecture, *paſſim.*

LECTURE XVII.

CONTAINING

MINERALOGY; *or the Art of Mining: With the previous Operations to* Metallurgy; viz. *Roaſting, Stamping, Waſhing, and the Buſineſs of Fluxes.*

1. WE are now entering upon a large, and extremely uſeful Branch of Chemiſtry; the Buſineſs of *Mineralogy* and *Metallurgy*. *The Subject.*

2. By *Mineralogy* we underſtand that previous Part of Metallurgy, which teaches the Ways of finding, judging, and digging Mines; with the Uſes of Salts and Earths for making Fluxes, in order to the aſſaying and ſmelting of Ores for their Metals. *Mineralogy, what.*

3. By *Metallurgy* we underſtand the Performance of thoſe ſeveral Operations required to ſeparate Metals from their Ores, for the Uſes of Life. And according to this Diſtinction we ſhall beſtow one Lecture upon *Mineralogy*, and another upon *Metallurgy*, in the Senſe we have here explained them. *Metallurgy, what.*

4. *Mineralogy* is an Art that requires a conſiderable Compaſs of Knowledge, before it can be practiſed to Advantage: For as this Art includes the Diſcovery, Sinking, and Working of Mines; it requires a competent Skill in the Nature, Effluvia, and Effects of mineral Matters, whether Earths, Salts, Sulphurs, Stones, Ores, Bitumens, *Requiſites to Mineralogy.*

mens, Gems, or Metals. It likewiſe requires a Knowledge of the internal Structure of the Earth, and its various *Strata*; with a competent Skill in ſubterraneous Architecture, Menſuration, Hydraulics, Levelling, and Mechanics; without which we can never judge what Mountain, Plain, or Valley, is proper to be dug; in what Manner to dig it; how to diſcharge the Water that may flow in upon the Works; how the Beds of Ore and Stone will dip, or run; how the various Kinds of Earths, Marble, and other mineral or metallic Matters, are to be cut through, or broken; or how the general Proceſs of Mining ſhould be conducted, in order to procure, with the leaſt Expence, or bring to open Day, the principal Matter or Ore required.

Qualifications of a Metalliſt.

5. And even when all theſe Difficulties are conquered, no more than half the Work is effected; and ſtill the End can never be obtained without a tolerably exact Knowledge of ſeveral chemical Operations; *viz.* Trituration, Torrefaction, Lotion, Calcination, Cementation, Fuſion, Amalgamation, Vitrification, Sublimation, Diſtillation, and the like: Whence it might be laid down as a Rule, That every directing Metalliſt ſhould not only be tolerably verſed in the ſeveral Parts of Natural Philoſophy, but particularly be well acquainted with *Chemiſtry.*

6. And perhaps it may not be improper to intimate, that many metallurgical Attempts have miſcarried, merely for Want of a competent Skill to conduct them. The under Workmen in this Way are generally a head-ſtrong, ignorant People, that cannot be managed without the Uſe of ſome good political Rules, and a Knowledge much ſuperior to their own. Yet how little ſoever the Art of Mineralogy may have been under-

The Succeſs of Mining.

underſtood, Hiſtory affords us numerous Examples of plentiful Fortunes and immenſe Treaſures raiſed from Mines, as well by private Perſons, as by particular States and Kingdoms. But the Vulgar, and even Philoſophers unverſed in Trade, generally reckon the Buſineſs of Mining unproſperous, and at beſt precarious and uncertain; eſpecially when compared with Agriculture, or other Arts exerciſed more in the open Day.

The Profit of Mines.

7. The Truth is, Mines are liable to many Contingencies; being ſometimes poor, ſometimes ſoon exhauſtible, ſometimes ſubject to be drowned, eſpecially when deep, and ſometimes hard to trace. Yet there are many Inſtances of Mines proving highly advantageous for hundreds of Years. The Mines of *Potoſi* are, to this Day, worked with nearly the ſame Succeſs as at firſt; the Gold Mines of *Cremnitz* have been worked almoſt theſe thouſand Years; and our *Corniſh* Tin-Mines are extremely ancient. In general, the Profit of Mines, compared with that of Agriculture, is immenſely greater in the ſame Time, ſo as to compenſate largely for its Uncertainty. Even Lead-Mines generally yield twice or thrice the Returns of the richeſt Soils, cultivated in the ordinary Manner, either by Nature or Art. What then ſhall we ſay of the Mines that are rich in the nobler Metals? The neat Profit of the Silver alone, dug in the *Miſnian* Silver-Mines of *Saxony*, in the Space of eighty Years, is computed at an amazing Sum *.

Accidental Diſcoveries of Mines.

8. Many Mines have been diſcovered by Accident. A Torrent firſt laid open a rich Vein of the Silver-Mine at *Friberg* in *Germany*. Some-

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* See *Petr. Albin. in Chronic. Miſn. Miner. German.*

times a violent Wind, by blowing up Trees, or overturning Rocks, has diſcovered a Mine. The ſame has happened by violent Showers, Earthquakes, Thunder, the firing of Woods, or even the Stroke of a Plough-Share, or a Horſe's Hoof.

The Art of Mining. 9. The Art of Mining does not wait for theſe favourable Accidents; but directly goes upon the Search and Diſcovery of ſuch mineral Veins, Ores, or Sands, as may be worth the working for Metal.

How to be practiſed. 10. The artificial Inveſtigation and Diſcovery of Mines depends upon a particular Sagacity, or an acquired Habit of judging, from particular Signs, that metallic Matters are contained in certain Parts of the Earth, not far below its Surface.

Signs of a Mine. 11. The principal Signs of a latent metallic Vein ſeem reducible to general Heads; ſuch as (1) the appearance of certain mineral Waters; (2) the Diſcolouration of the Trees or Graſs; (3) Pieces of Ore on the Surface of the Ground; (4) the Riſe of warm Exhalations; (5) metallic Sands, and the like: All which are ſo many Encouragements for making a ſtricter Search near the Places where any Thing of this Kind appears. Whence Rules of Practice might be formed for reducing this Art to a greater Certainty.

The Art of Boring. 12. But when no evident Signs of a Mine appear, the ſkilful Mineraliſt uſually bores the Earth in ſuch Places as, from ſome Analogy of Knowledge, gained by Experience or by obſerving the Situation, Courſe, or Nature of other Mines) he judges may contain Metal.

13. This Method of Boring conſiſts in the Uſe of a Set of Scooping Irons, made with Joints, ſo as to be lengthened at Pleaſure, and thruſt down to a conſiderable Depth below the Surface of the Earth,

Earth; ſo as when drawn out again to bring back Samples of the Earth, or mineral Matter, from the Depth to which the Iron deſcended; much after the Manner that Samples of Sugar are taken out of the Hogſhead by the Inſtrument called a *Reſt*.

When Mines may be dug to advantage.

14. After a Mine is found, the next Thing to be conſidered is, whether it may be dug to Advantage. In order to determine this, we are duly to weigh the Nature of the Place, and its Situation, as to Wood, Water, Carriage, Healthineſs, and the like; and compare the Reſult with the Richneſs of the Ore, the Charge of Digging, Stamping, Waſhing, and Smelting. This is a Matter of common, civil, or œconomical Prudence.

15. Particularly the Form and Situation of the Spot ſhould be well conſidered. A Mine muſt happen either (1) in a Mountain, (2) in a Hill, (3) in a Valley, or (4) in a Flat. But Mountains and Hills are dug with much the greateſt Eaſe and Convenience; chiefly becauſe the *Drains* and *Burrows*, as the Miners call them, that is, the *Adits*, or *Avenues*, may be therein readily cut, ſo as both to drain off the Water, and to form Gangways for bringing out the Load, or Ore, &c.

Mines, where to be opened.

16. In all theſe four Caſes *, we are to look out for the Veins, which the Rains or other Accidents may have laid bare; and if ſuch a Vein be found, it may often be proper to open the Mine in that Place, eſpecially if the Vein proves tolerably large and rich: Otherwiſe the moſt commodious Place, for Situation, is to be choſen for the Purpoſe; *viz.* neither on a Flat, nor on the Top of a Mountain, but on its Sides: For the Mineraliſt is always to exerciſe his Judgment

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* See §. 15.

in the due Choice of a Place to begin the Work.

The beſt Situation of a Mine. 17. The beſt Situation for a Mine is a mountainous, woody, wholeſome Spot, of a ſafe, eaſy Aſcent, and bordering upon a navigable River. Such a Place therefore being the Standard of Goodneſs, all others may be judged of as they approach to, or recede from it.

Requires Wood. 18. Wood is indiſpenſably neceſſary for makeing the neceſſary Inſtruments, Engines, and Huts; as alſo for fencing the Pits, or Avenues, and ſupporting the Rock, where large Caverns are made by digging away the Ore: And again, for ſupplying Fewel to the melting Works; unleſs where Pit Coal will ſerve the turn. But though no Wood or Coal ſhould grow upon the Spot, it may often be ſupplied by Means of a navigable River, or cheap Carriage. And thus there are ſome rich Mines, in the hotter Climates, without ſo much as a Shrub growing near them.

Water. 19. Plenty of Water ſhould never be wanting, and is beſt ſupplied by a River, from which it may be commodiouſly derived, by Pipes, into the Lavaderos, Smelting-Huts, *&c.* or even brought into the Burrows themſelves, and made to work the ſubterraneous Machines. Theſe are Conveniencies not to be expected from caſual Rains, or the Torrents of the Mountains.

Good Roads. 20. The Roads and Conveniencies of Carriage, to and from the adjacent Parts, muſt be likewiſe regarded; as well for the Sale of the Metal produced, as the Conveyance of Goods and the Neceſſaries of Life to the Workmen: For it rarely happens that Proviſions are afforded by the Spot where Metals are found.

21. The Places abounding with Mines are generally healthy; as ſtanding high, and every

Way expoſed to the Air: Yet ſome Places where Mines are found prove poiſonous, and can by no means be dug, though ever ſo rich. The Way of examining a ſuſpected Place of this Kind is, to make Experiments upon Brutes, by expoſing them to the Effluvia or Exhalations, in order to find the Effects thereof.

And wholſome Air.

22. But a conſiderable Advantage may ſometimes be made, without the Labour and Expence of Digging: For as Springs and Rivulets are frequently the Outlets of Mines, it may happen that the Sand of ſuch Waters ſhall be worth the waſhing for Metal; in which Manner large Quantities of Gold Duſt are often procured. And hence it appears to be, that the Sands of many rapid Rivers, and even the Sands of the Sea in ſome Places, contain Gold; though the latter in ſo ſmall a Proportion as ſeldom to be worth the Waſhing. But the Sand of ſuch Rivers wherein ſtamped Ores are continually waſhed may frequently deſerve to be aſſayed.

Metals obtainable without Mining.

23. The Veins of a Mine differ greatly from each other, in Depth, Length, and Breadth. Some ſtretch obliquely from the Surface towards the central Parts of the Earth; and theſe are called *deep Veins*: Others lie ſhallow and circular, ſo as to encompaſs a large Space; theſe are termed *ſpreading Veins*: Others poſſeſs a great deal of Space, both in Length and Breadth; and theſe are called *accumulated Veins*; being no more than a Space poſſeſſed by a Group of Foſſils of one certain Kind. But to give the Hiſtory of Veins, and Fibres, which are ſmaller Veins, their Differences, their Directions, their Interſections, their different Goodneſs, their Diſcontinuations, their Riſing, Falling, *&c.* would be a large Work. Let it, however, be obſerved, that theſe Things ſeem to proceed in a certain

The different Veins.

order,

order, though the Laws thereof have not been ſo well obſerved as to afford us ſure Rules of Practice: Whence it ſometimes happens, that after a Vein has been ſucceſsfully traced for ſome time, it dips, breaks off, or takes a different Courſe, leaving the Workmen as it were at Fault.

How to be traced.

24. When a Vein of Ore is found, and all Things prepared for the Work, if the Vein be of the deep Kind * it is firſt to be laid bare, and a Pit to be ſunk upon it; at the Mouth whereof a Shed is to be raiſed, and a Crane, or Barrel and Winch, fixed, for drawing up the Ore. The Pit is to be ſunk either perpendicular or oblique, according as the Vein happens to run.

And dug.

The Burrows, how made.

25. It is alſo uſual, in this Caſe, to cut a Burrow, or Adit into the Side of the Hill. This Burrow is uſually cut twice as high as wide, that the Workmen may commodiouſly paſs along it with their Barrows and Burdens; being for that Purpoſe uſually about ſeven Foot and a half high, and almoſt four Foot wide. If this Side Pit reaches to the ſunk Pit, it becomes a true Burrow, open at both Ends; and thus renders the Work more facile and commodious, as the Ore may be now wheeled out in Barrows, inſtead of being craned up to the upper mouth of the Pit. After the ſame Manner it is uſual to dig many Caverns into the Sides of the Mountain, in order to ſcoop out the Ore: So that ſometimes there are thus ſeveral Burrows made, to the Eaſe and Advantage of the Work.

The Digging various. By the Spade.

26 The Art of Digging the Veins varies according to the Nature of the Vein, or according as it is ſoft or hard. The ſoft Vein is generally dug with the Spade, and turned out into

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* See above, §. 23.

wooden Trays, placed underneath to receive it: But the hard Veins are knocked out with a Gad, or Kind of Chizzel, and Hammer. But if the Ore is ſo hard as to be incapable of breaking in this Manner, they uſually ſoften it with Fire; which has the Power of rendering the hardeſt and moſt flinty Stones brittle and friable. But a ſtill more expeditious Method is the working with Gunpowder; by Means whereof much of the hardeſt Rock may be ſhivered and ſplit in a very little Time; a ſmall Parcel of Powder being laid in a long Hollow cut for the Purpoſe, after the Nature of a Gun-Barrel, and fired as it were at a Touch-hole; a ſmall Vent, where the Quick-match is applied, being left for the Purpoſe, and the reſt of the Orifice being hard ſtopped up with Clay.

By the Gad.

By Fire.

By Blaſting.

27. The Manner of purſuing and digging all Sorts of Veins, the Ways of under-propping, and diſcharging the Water from the Works, the ſinking of Air-ſhafts, curing of Damps, and the like, we have no time to deſcribe *; our more immediate Buſineſs being the Treatment of the Ore, after it is dug and brought to open Day. For this Purpoſe there are certain previous Operations required, of which we propoſe to exhibit Examples. Our *firſt* Experiment, therefore, will ſhew the Method of Roaſting ſulphureous or arſenical Ores; the *ſecond* will ſhew the Method of Stamping and Waſhing of Ores; and the *third*, the Method of preparing Fluxes.

The Deſign of the following Experiments.

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* See *Agricola de re metallica.*

EXPERIMENT I.

The Method of Roaſting Ores.

Mundic roaſted. 28. We took a Pound of the common *Corniſh* Mundic, and breaking it into ſmall Lumps, expoſed it upon the Grate of a Furnace, whilſt the Fire was made below; and thus at firſt we gently heated and torrified the Mundic, but afterwards by Degrees increaſed the Fire, ſo as to make the Lumps glow, or appear red hot; in which State we kept them for half an Hour, or till no more ſulphureous Vapour or Stench roſe from them.

The Experiment explained. 29. This Experiment ſhews the common Method of Roaſting Ores, in order to diſcharge their ſulphureous, arſenical, or antimonial Parts, that might otherwiſe hinder their Fuſion, or elſe carry off a conſiderable Proportion of the truly metallic Matter in melting. For fear this metallic Matter ſhould fly off, we made the Fire gentle at firſt; but increaſed it, by Degrees, till the Lumps became red hot, becauſe otherwiſe the Sulphur would not quit its hold; for Sulphur requires a naked Fire and the Aſſiſtance of the open Air, before it will burn, or go entirely off *.

And applied, to the kindly Ores. 30. The richer and more tractable Ores have no Occaſion to undergo this previous Operation of Roaſting, but are uſually committed to Fuſion ſoon after being dug up, and ſeparated from their Stone, or Mine. However, if they contain any conſiderable Quantity of Sulphur, or Arſenic, it is uſual to roaſt even theſe a little.

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* See *Lect.* II. *paſſim.*

31. But ſome Copper Ores are ſo ſtubborn and refractory, or hold their Sulphur ſo tenaciouſly, as to require many Roaſtings before they will let it go: being either ſtamped or melted after every Operation, ſo that all the Parts may, at ſeveral Times, be equally expoſed to the Fire, and have their Sulphur diſcharged. *To the more ſtubborn Ores.*

32. In the large Way of Buſineſs this Operation is uſually performed in a Trench cut ſomewhat aſlope in the Ground, that the Air may have the freer Acceſs at the Bottom: they firſt place a Layer of Billet-Wood in this Trench, and upon that a Layer of the Ore, in little Lumps, and ſo continue, interpoſing a Layer of Wood and a Layer of Ore, for three or four Stories; when the Pile being compleated, they ſet Fire thereto, and make it continue to burn ſlowly for ſeveral Days together, during which Time there riſes a large Quantity of ſulphureous Vapour, that may be perceived to a conſiderable Diſtance. *In the large Way.*

33. But when the Ore, by repeated Roaſting, Stamping, and Fuſing, is become tolerably pure, they now finiſh the Operation by throwing it into a particular Furnace, having a Funnel to increaſe the Draught; ſo as to make the Fire the ſtronger, and diſcharge the ſulphureous Fumes in greater Plenty. And this Furnace is ſo contrived, that the open Flame of the Wood may play directly upon the Ore; whence all its volatile Part is ſeparated, and the Remainder left fit for the laſt Stamping and Waſhing.

34. When the Ores contain a large Quantity of Sulphur, this uſually ſweats out and runs down into Cavities made on Purpoſe to receive it; whence it may be ladled out, and caſt into Moulds. But perhaps the moſt frugal Method of roaſting Ores, ſo as to ſave, or collect, all the *The Sulphur, how collected.*

the Sulphur, or Arſenic, they contain, is not generally known and practiſed: For in the common Way, a large Proportion is loſt, which might be collected by Means of a proper Hood, in the Form of Flowers; and alſo the riſing Fume might, by a particular Structure of the Furnace, be made to paſs into a large Veſſel of cold Water, and there be condenſed; as we ſee in certain chemical Diſtillations and Sublimations.

Vitriol obtainable in the waſhing.

35. After the poorer and more ſtubborn Sorts of Copper-Ore have been thus ſucceſſively roaſted, and come to be quenched in Water, or waſhed, they often impregnate the Water with a vitriolic Matter; ſo that ſometimes profit may be made by evaporating theſe Waters, and ſuffering the Vitriol to ſhoot: For the acid Part of the Sulphur, here ſeparated by the Fire, is greatly diſpoſed to enter the metallic Part of the Ore, and diſſolve it; ſo as to form an actual blue Vitriol, or Vitriol of Copper, which ſells for a conſiderable Price.

Roaſting generally profitable.

36. And here it ſhould be remembered, that Ores rarely yield the leſs Metal for Roaſting; unleſs the Fire were made too ſtrong, eſpecially at the firſt: For when the Yield proves ſmall, the general complaint of the Smelters is, That the Ore, when ſent to their Furnace, was too little roaſted; though indeed the fault is often their own, in neglecting to make their Fire ſufficiently briſk and ſtrong from the firſt; which is a very conſiderable Secret for increaſing the Yield of an Ore.

Tho' not always in imperfect Ores.

37. There are, however, ſome Reaſons to believe, that many imperfect Ores loſe conſiderably of their Metal by Roaſting, eſpecially when they are mixed with arſenical, or antimonial, Matters, which have a known Property of volatilizing the impurer Metals, and carrying them

off in Fume: Whence, doubtleſs, it is that ſome poor Ores and Mundics are commonly treated with little Succeſs.

38. The Remedy in this Caſe we apprehend to be the due Uſe and Application of ſome *fixing Subſtances*, whether of an abſorbent, alkaline, or neutral Nature; ſuch as Quicklime, Kelp, or Pot-Aſh, dry River-Mud, Clay, Iron-Filings, or the like, mixed or ſtratified along with the Ore. And by certain Additions of this Kind, we doubt not but the Yield of ſome poorer Ores might be conſiderably increaſed. *This Inconvenience remedied.*

39. The Buſineſs of Roaſting Ores may be improved, and reduced to a few eaſy Rules. (1) We ſee it is of two Kinds, or ſimple and compound; that is, either with or without Addition. No Addition is wanted when the Ore proves rich, or in itſelf nearly of a metallic Nature, as ſome Ores are found to be. But Additions are principally required, when arſenical, antimonial, or ſulphureous Matters are naturally mixed with the Ores *. *Roaſting reduced to Rule, with regard to Additions.*

40. (2) The Fire is to be ſo regulated, from the firſt, that only the lighter, or more volatile, ſulphureous, or arſenical Fumes may go off; otherwiſe the more metallic Part alſo would fly away, and, without ſome proper Contrivance to catch it, be loſt. Yet the Ore muſt feel the force of an open Flame at laſt; otherwiſe all the Sulphur, Arſenic, Antimony, and other immature mineral Subſtances, will not be diſlodged. *The Fire.*

41. (3) The more theſe immature Subſtances abound in the Ore, the gentler the Fire ſhould be at firſt; and when the greater Part of them is thus exhaled, the Fire is to be quickened by a freer Admiſſion of the external Air.

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* See §. 38.

And Waſhing. 42. (4) Laſtly; Where ſuch fixing Additions are uſed as are not metalline, for Example, Lime, Mud, &c. the unmetallick Parts ought again to be ſeparated by Stamping and Waſhing, before Fuſion, which would otherwiſe be hindered, or uſeleſsly encumbered.

EXPERIMENT II.

The Method of Stamping and Waſhing of Ores.

Mundic ſtamped and waſhed. 43. We took the Mundic roaſted in our former Experiment, beat it fine in a metalline Mortar, and ſearced it; then putting it into a Buddling-Diſh, we waſhed it in ſeveral Waters, taking care to ſeparate the heavier Portion from the lighter, and drying this heavier Part, which is always the more metallic.

Waſhing and Stamping not always neceſſary. 44. Theſe Operations of Stamping and Waſhing are not neceſſary in the richer Sorts of Ores, but are often abſolutely required in the poorer and more flinty Kinds. If a large Quantity of mere ſtony Matter adheres to the Ore, it is ſometimes knocked off with Hammers; ſo as to leave the more metallic Part free from this barren or ſuperfluous Subſtance.

Hard Ores, how ſoftened 45. If the Ore ſtill proves hard and flinty, it is ſometimes ſoftened by lying, for ſeveral months, expoſed to the open Air, which thus renders it fit for the Stampers; though it ſometimes alſo requires to be heated, or ignited, and quenched in Water, to fit it for that Purpoſe. Thus a large Heap of hard, and otherwiſe untractable, Ore may be heated red hot, by interſperſing it with Billets, and ſetting them on fire; after which it may readily be quenched, and rendered friable, by throwing cold Water upon it, or by paſſing a ſmall Stream of Water through it, derived from ſome adjacent River. And ſometimes this Operation muſt be repeated, before the Ore will grow ſoft and tractable.

46. It is uſual to ſtamp moſt Ores in a State of Moiſture or Wetneſs, to prevent the Avolation of their Duſt or Powder; but eſpecially ſuch as require much waſhing to ſeparate their barren and lighter earthy Parts, which would otherwiſe uſeleſsly encumber the melting Furnace. To perform this Stamping the more commodiouſly, a Stream of Water is made to paſs under the Stampers; ſo as to make various windings and turnings, and, in Part, run into certain Cavities, made on Purpoſe to catch and detain the heavier Matter, whilſt the lighter is waſhed away to a greater Diſtance by the Current.

Ores how beſt ſtamped in the large Way.

47. But the Method of waſhing the Ores of the nobler Metals is more exact and curious; as in waſhing of Sand for Gold, on the Banks of the *Rhine* and *Danube*, where Gold is frequently found, eſpecially in ſuch Places where the Sand is raiſed into large Heaps, or a Kind of Mountains, by the Rapidity of the Stream.

The Ores of the nobler Metals how waſhed.

48. Theſe Sands are uſually waſhed by the Hand, in a long Trough, made for the Purpoſe, with a Deſcent or Current, and lined at the Bottom with Flannel; for thus the Sand being artificially agitated with the Hand, the lighter and larger ſtony Matter riſes uppermoſt, whilſt the heavier deſcends, and is catched in the Pores of the woolly Cloth at the Bottom; in the mean Time the lighter Matters are waſhed farther off by a Stream running down the Declivity. When the Flannel has thus collected a conſiderable Quantity of the richer metallic Matter, the whole Cloth may be eaſily taken off, and rinſed in a proper Veſſel of Water, where all

Fine Gold Sand how waſhed.

all the metallic Matter, before adhering to it, readily falls off, and ſinks to the Bottom of the Veſſel; and then, the Water being decanted, the Metal may be collected alone and dried. And this is the Method of procuring the Gold where the Sand is fine, or extremely ſmall.

The coarſer how treated.

49. In the larger Works, or where the Gold is mixed with big Sand, Gravel, or Stones, they make Uſe of Wire-Sieves, whoſe Meaſh is always of one certain Size; ſo as readily to tranſmit the fine Sand, or Gold Duſt, and retain the larger Gravel and Stones behind: For it is extremely rare to meet with a Grain of Gold, in the Sands of Rivers, ſo large as a Barley-Corn. Whence this Method by the Sieve is highly ſerviceable, and conducive to the former Operation: For though a large Quantity of fine Sand thus paſſes the Sieve, it may be readily ſeparated in the Trough, after the Method already deſcribed *.

The End of Stamping and Waſhing.

50. And this may ſuffice to ſhew the general and particular Methods of Stamping and Waſhing Ores. We ſee the End of theſe two previous Operations is to get rid of the Matters which are not metalline; that ſo the Furnace may not be uſeleſsly employed upon ſuch Subſtances as will themſelves yield no Metal in the Fire, and only hinder the metallic Parts of the Ore from coming together, and affording a Yield anſwerable to the Expence and Trouble of the Fuſion.

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* § 48.

EXPERIMENT III.

Ways of preparing the ſtrongeſt Fluxes.

51. We took four Ounces of red Lead, an Ounce of White Sand in Powder, and two Ounces of dry decrepitated Salt, and mixed them all well together in a Mortar; this Mixture we put in a clean *Heſſian* Crucible, fitted with a Cover, and fuſed it in a Wind-Furnace for a Quarter of an Hour; then taking it out, and letting it cool, we broke the Crucible, and found the Salt at top, and a pure Glaſs of Lead at the Bottom: This Glaſs we carefully ſeparated and kept apart, as a powerful Flux. *Glaſs of Lead prepared as a Flux.*

52. The Salt is of no other Uſe in this Operation, than to ſerve as a Flux to the Sand, and make it more readily unite with the Red Lead; ſo as to form a Glaſs without any great Violence of Fire, or the Neceſſity of detaining it long therein. So that by this Means a Glaſs of Lead may be readily prepared for the Purpoſe of artificial Gems *, or other Uſes. *Salt, why uſed therein.*

53. This Glaſs of Lead is an extremely uſeful Flux in the Buſineſs of aſſaying; and when kept long in Fuſion, paſſes through the Pores of any common Crucible, almoſt like Water through a Sieve; ſo as, upon the Teſt, readily to vitrify, and carry off, all Sorts of metalline and mineral Matters, except Gold and Silver: On which Property, therefore, the Art of Cupelling depends. *The Uſe of this Glaſs.*

54. Fluxes ſeem reducible to two general Kinds; *viz.* the *vitreous* and the *ſaline*. By the *Fluxes of two Kinds;*

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* See *Lect.* XIV. *Exp.* II. and V.

vitreous

viz the vitreous. *vitreous* we underſtand all thoſe which either have of themſelves, or readily aſſume, a glaſſy Form in the Fire; among the Principal whereof we reckon the Glaſs of Lead, the Glaſs of Antimony, and Borax.

and ſaline. 55. By the *ſaline* Kind of Fluxes we underſtand all thoſe that are compoſed of Salts, whether Tartar, Nitre, fixed Alkali, or the like. And among the Principal of this Kind we reckon the Black Flux, which we formerly ſhewed how to prepare *; alſo Sandiver, Kelp, *&c.*

Their different Uſes. 56. The vitreous Kind ſeem more immediately deſtined to act upon the ſtony or vitreſcible Matter, wherewith ſtubborn Ores are frequently mixed; and the ſaline Kind, to act more immediately upon the Ore itſelf, for the due Excluſion or Separation of the Metal.

Some Ores require no Flux. 57. The more kindly Ores require no Flux to make them run thin, or to afford all the Metal they contain. And ſometimes Ores are ſo kindly as to contain their own Fluxes within themſelves. Thus we have met with Copper-Ores, which being barely ground to Powder, and melted, without any Addition, in a common Wind Furnace, have yielded as much, or even more pure Metal at the firſt Operation, than we could obtain from them by Means of the uſual Fluxes. Whence we ſee that artificial Fluxes are not always neceſſary; or that the principal Uſe of them is for the ſtubborn or leſs *Metallurgy improveable by diſcovering cheap Fluxes.* tractable Ores. And theſe are ſometimes ſo exceedingly hard to fuſe, and bring to a metalline Form, that it requires the utmoſt Power of Art to treat them advantageouſly in the larger Way of Buſineſs, where no conſiderable Expence can uſually be allowed for Fluxes.

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* See *Lect.* I. *Exp.* II.

58. On

Metallurgy.

58. On this account it is that many Mines remain unwrought, as being intractable without great Charges. Whence the Improvement of the Buſineſs of Fluxes, ſo as to render them cheap and effectual, might greatly contribute to the Improvement of Metallurgy. We would therefore recommend to farther Enquiry what Matter it is, in the more ſoft and tractable Ores, which renders them ſo fuſible, and eaſy to part from their Metal. Certain Experiments which we have made with this View ſeem to ſhew, that in Copper-Ores it is a Kind of bituminous Subſtance, capable of melting, by a ſtrong Heat, into a ſoft and black kind of Glaſs.

The cheap ſimple Fluxes.

59. Some of the moſt powerful and cheap ſimple Fluxes hitherto known are dried Wine-Lees, dried Cow-dung and Horſe-dung, dried River-Mud, Fuller's Earth, Iron Filings, common Salt, Glaſs, Kelp, Pot-Aſh, Sandiver, *&c.* which may be uſed in the larger Work; as Nitre, Tartar, Borax, Sal-Ammoniac, Mercury-Sublimate, *&c.* may in the ſmaller, or for the making of Aſſays.

Cheap compound Fluxes.

60. As for compound Fluxes, they are numerous; almoſt every Operator having his favourite one. And certainly ſome Fluxes are better adapted than others to certain Ores. But perhaps a few general ones might be fixed upon, which ſhould ſerve inſtead of all thoſe hitherto commonly known and uſed. We will here recommend three, which are powerful, almoſt general, and not expenſive.

61. (1) Take of Nitre, prepared by long boiling it in Lime-Water, of Sea-Salt melted in the Fire, Sandiver, and dry Wine-Lees, each one part; Glaſs of Lead, three Parts; and powdered Glaſs, eight parts: mix them all well together.

This Flux added, in an equal Weight, will fuſe a very ſtubborn Ore.

62. (2) For a ſtill ſtronger, take equal Parts of white Tartar, common Salt, and Nitre, prepared as above; calcine them to a white Powder, and mix therewith its own Weight of Glaſs of Lead; and of this Flux add two Parts to one of the ſtubborneſt Ore.

63 (3) For a powerful ſaline Flux take of the ſtrongeſt Soapboiler's Lees four Pounds, white Tartar and common Salt, melted in the Fire, each one Pound; boil them together with five Gallons of human Urine, to a dry Salt. This Flux is particularly proper where Sulphur and Cobalt abound, and render the Ore very refractory.

The Improvement of Fluxes.

64. But the great Secret in the making and adapting of Fluxes, is not only to ſeparate the Metal already ripened in the Ore, but even to mature and ripen the crude or immature Part of the Ore in the Fire. Something of this Kind, we apprehend, may be effected; as having reaſon to believe, that certain Fluxes, will obtain a larger Yield of Metal from certain Ores, than other Fluxes in common Uſe, though eſteemed of the beſt, and though they are perhaps of the deareſt Kind. Thus clean Iron Filings will often do more than Borax. But as the Scales and Crocus, or Ruſt, of Iron have been commonly uſed, inſtead of pure and perfect Iron itſelf, for a Flux, few Operators appear acquainted with the Excellence of perfect Iron employed for this Purpoſe. Many Advantages alſo are now commonly reaped by a prudent Mixing of one Ore with another of the ſame Denomination, and with the Slags or Recrements of Metals, in the Way of a Flux.

AXIOMS

AXIOMS *and* CANONS.

1. We learn from the preceding Enquiry, that to practiſe Mineralogy and Metallurgy to advantage, a conſiderable Knowledge in Natural Philoſophy and the Operations of Chemiſtry is required *a*).

2. That many Miſcarriages in mineral Attempts have been owing to the Want of a competent Skill in Mechanics, Hydraulics, and Chemiſtry *a*).

3. That the Profit attending the ſcientifical Working of Mines is generally greater, and upon the whole more conſiderable, than that of Agriculture, or Merchandize *b*).

4. That there are two Ways of diſcovering Mines; *viz.* by Accident, and by Art: The latter whereof belongs to the intelligent Mineraliſt *c*).

5. That the Art of diſcovering Mines depends upon a certain Sagacity, which may be acquired by Uſe and Practice; or upon the Obſervation of particular Signs that generally denote a Mine; and again upon the Method of Boring, according to ſome Analogy of Knowledge, gained by being converſant with the common Appearances, Situations, and other Phænomena of Mines *c*).

6. That the Art of diſcovering Mines is reducible to Rule, ſo as not to be mere Conjecture, or Gueſs-work *c*).

7. That in general, Mines are to be firſt opened where a Vein is laid bare by accident or otherwiſe, eſpecially if it prove large or rich: But where no ſuch Encouragement appears, the

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a) § 4—6. and Exp. I. II. III.
b) § 4—6.
c) § 8——13.

ſides of Hills are preferably to be choſen for an opening *a)*.

8. That a deliberate Conſideration, and a competency of oeconomical Prudence, are uſually required to determine before-hand, whether a Mine, after it is diſcovered, may be wrought to Profit *b)*.

9. That the moſt perfect Situation of a Mine is to be mountainous, woody, eaſy of Aſcent, healthy, bordering upon a navigable River, and good Roads *b)*.

19. That Metals may be ſometimes obtained to Advantage without Digging; or barely by waſhing the Sands of certain Springs and Rivers *c)*.

11. That mineral Veins differ greatly from each other, and accordingly require different Methods of Digging, which may be reduced to ſtandard Rules of Practice *d)*.

12. That the Buſineſs of Mining is improveable by diſcovering better Methods of preventing or curing Damps in Mines, rendering poiſonous Mines wholeſome, or defending the Bodies of the Workmen againſt their ill Effects; as alſo by diſcovering better Methods of raiſing or diſcharging the Waters, following the Veins, breaking the Rock, bringing up the Ore, *&c. d)*.

13. That the End of Roaſting Ores is to diſcharge their ſulphureous, arſenical, antimonial, or other rapacious Matters; which would otherwiſe carry off the purer Metal in the melting Furnace, and defraud the Account *e)*.

14 That the richer Ores require neither Roaſting, Stamping, nor Waſhing; but may be di-

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a) § 14—16. *b)* § 14——21. *c)* § 22, 47—49.
d) § 23—26. *e)* Exp. I.

rectly committed to the Smelting-Furnace, without Flux or Addition *a*).

15. That in order to roaſt Ores in Perfection *per ſe*, the Fire ſhould be gentle at firſt, and afterwards increaſed to a Degree of Ignition in the Ore *b*).

16. That ſome Ores, joined with rapacious mineral Matters, may be advantageouſly mixed, or ſtratified, in Roaſting, with proper fixing Ingredients *b*).

17. That Ores are ſeldom rendered the poorer, but generally the richer, for Roaſting; unleſs the Fire at firſt be made too ſtrong *b*).

18. That the Buſineſs of Roaſting Ores is improveable, and reducible to a few eaſy Rules, with a View to render the Ore more pulverable, and diſcharge its volatile, ſulphureous, and arſenical Parts; which, if retained, would, in ſtrong Fuſion, partly prevent the Separation of the purer Metal, and partly carry it off into the Air *b*).

19. That Metals, in their Ores are not thoſe fixed Bodies they appear to be in the Bars or Ingots, into which they are brought by metallurgical Operations *a*).

20. That the Operations of Stamping and Waſhing are required only in the hard, flinty, and poorer Ores; the Deſign of theſe Operations being merely to ſeparate the uſeleſs terreſtrial, or flinty and ſtony Parts, which would otherwiſe encumber the Furnace and leſſen the Yield.

21. That ſome hard Ores, may be ſoftened, or rendered fitter for Stamping and Waſhing, barely by lying expoſed to the open Air, which ſeems to turn ſome Parts of the Ore into a ſaline

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a) Exp. I. II. III.

b) Exp. I.

matter, or Vitriol; whence a Kind of Friability or Softneſs is communicated to the Reſt a).

22. That the hardeſt or ſtubborneſt Ores may be ſoftened, and rendered fitter for the Stampers, by being firſt ignited, and then quenched in Water; eſpecially if this Operation be ſeveral Times repeated b).

23 That the two Operations of Stamping and Waſhing are, in good Meaſure, reducible to one, in the ordinary Ores; the Courſe of the Water being ſo directed under the Stampers, as immediately to carry off the lighter ſtony Matters, and leave the heavier or more metallic Parts behind b).

24. That the Sands of certain Rivers may, by a ſlight manual Operation, be ſometimes waſhed for their Gold to conſiderable Profit c).

25. That the waſhing of Sand for Gold may be conſiderably expedited, by a proper Uſe of the Sieve b).

26. That Glaſs of Lead is a powerful Flux; ſo as to be capable of vitrifying, and carrying away with itſelf upon the Teſt, all the metallic or mineral Matters that are not either Gold or Silver d).

27. That the vitreſcible Claſs of Fluxes are more adapted to operate upon the ſtony Parts of Ores, and the ſaline Claſs upon the Ores themſelves, ſo as to ſeparate their Metal d).

28. That the Buſineſs of Aſſaying and Refining Gold and Silver, depends upon that Property which Lead and the Glaſs thereof have of vitrifying, and carrying off upon the Teſt, all the known Matters, except the two nobler Metals d).

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a) *Exp.* II. See alſo *Lect.* III.
b) *Exp.* II.
c) § 22, and *Exp.* II.
d) *Exp.* III.

29. That ſome Ores naturally contain their own Fluxes, and are therefore beſt aſſayed and ſmelted *per ſe* *a*).

30. That the Buſineſs of Metallurgy might be conſiderably improved, by diſcovering a cheap and general Set of powerful Fluxes *a*).

31 That an Enquiry into the Nature of the fuſible Matter, naturally contained in the more kindly Ores, might lead to a Diſcovery of ſome cheap and powerful Fluxes *a*).

32. That the large Number of compound Fluxes might be reduced to a few general Kinds, capable of performing as much as all of them ſeverally *a*).

33. That the greateſt Improvement of Fluxes depends upon making and uſing them ſo as to maturate the Ore, or otherwiſe cauſe a larger Yield than can be procured by the common Fluxes *a*).

34. That ſuch maturating Fluxes may be, in ſome Degree, obtained by a farther Knowledge of the Properties, Affinities, or Relations betwixt Metals and Metals, Metals and Minerals, Ores and Ores, or Minerals and Minerals *a*).

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a) *Exp.* III.

LECTURE XVIII.

CONTAINING

METALLURGY; *or the Art of* Aſſaying, *and working Metals from their Ores.*

The Subject. HAVING already conſidered the ſeveral Parts of *Mineralogy* *, as previous to the Art of *Metallurgy*, we now come to Enquire into the Operations of Metallurgy itſelf.

Metallurgical Operations of two kinds. 2. Theſe Operations are of two kinds, or ſmaller and larger; with regard to which the whole of Metallurgy may be divided into two Parts; *viz Aſſaying*, and *Smelting*.

Aſſaying. 3. By Aſſaying we underſtand the Method of determining by Trial, in Miniature, what will be the Yield of an Ore in pure Metal when it comes to be wrought in the larger Furnace.

And Smelting. 4. And by Smelting we underſtand the ſeveral Ways of reducing Ores to pure Metal in the large Way of Buſineſs, ſo as to fit the Produce for the civil, mechanical, and oeconomical Uſes.

Deſign of the Experiments. 5. We ſhall here enquire into both theſe Parts of Metallurgy, or conſider as well the Smelting as the Aſſaying of Ores. Thus the *firſt* Experiment will ſhew the Method of Aſſaying and Smelting Gold and Silver; the *ſecond* will ſhew the Method of ſeparating Gold from Silver; the *third* will ſhew the Method of Aſſaying and Smelting

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* See *Lect.* XVII.

ing Copper, Tin, Lead, and Iron; the *fourth* will ſhew the Method of making Braſs and Princes Metal; and the *fifth* will exhibit the Method of making Steel.

EXPERIMENT I.

The Method of Aſſaying and Smelting Gold and Silver Ores.

6. (1) We took a Penny-weight of Silver-Ore reduced to fine Powder; and having put it together with half an Ounce of Lead cleared of its Silver, into a little flat Eſſay-Crucible, under a Muffle, in the Teſting Furnace, we continued to Uſe a gentle Heat till the Lead had imbibed the powdered Ore at leaſt its metallic Part, and ſeparated the more ſtony Matter in form of a glaſſy *Scoria* at the Top. (2) We now took out the Lump of Lead, impregnated with the Silver of the Ore, and placed it upon a *Teſt*, which had been heating, or nealing, all this while under the ſame Muffle; and working with a proper Degree of Heat, till all the Lead was either evaporated, vitrified, or ſunk into the Teſt, we found a little Bead, or Grain, of Silver left behind; which Grain, or Bead, being exactly weighed, and compared with the original Weight of the Ore, gives the proportion of Silver contained in the Ore, that is, determines its Richneſs: And the ſame Method is equally applicable to Gold-Ores, Sand, or any other Matters containing Gold, Silver, or a Mixture of both.

Silver Ore aſſayed by Teſting.

7. This Operation is uſually called Teſting, or Cupelling; and exhibits almoſt the whole Art of the Aſſay Maſter and Refiner. We ſee the Proceſs conſiſts of two Parts; *viz. Imbibition*, and *Separation*: For the Lead is firſt made to drink

The Operation explained.

drink in all the Silver from the Ore; and then the ſame Lead is entirely ſeparated from the Silver. And in this Manner alſo are Eſſays taken of Silver Coin, or any Mixtures of the nobler with the ignobler Metals: For when the Operation is exactly performed, no other Metals, beſides Gold and Silver, will be left upon the Teſt.

Its Rationale.

8. The phyſical Reaſon of the preſent Proceſs deſerves to be enquired into. The Laws or Principles on which it depends are theſe: (1) When the imperfect Metals, or other Minerals, are added to melted Lead, ſome of them will not enter into it, but remain floating on its ſurface, in form of a hard *Scoria*; which is the Caſe with Iron: (2) Others enter it, but gradually emerge again; as Tin: (3) Others totally exhale; as Regulus of Antimony, and Arſenic: (4) Others again burn to Aſhes, or run into Glaſs, along with the Lead; as does Copper: But (5) neither Silver nor Gold is capable of flying off, burning to Aſhes, or turning to Glaſs, by being detained in melted Lead: Whence theſe two Metals, of courſe, remain pure and ſeparated from all the Reſt, at the End of the Operation. And thus we find, that the Gold and Silver remaining all the Time mixed among the Lead, without going into Glaſs, continually ſink down from the ſhelving ſides of the Teſt, towards the Bottom of the Hollow, along with the Lead; which being at length totally conſumed, and the Fire unable to keep Silver or Gold melted without ſome Addition of Lead, they neceſſarily grow rigid, and fix in a ſmall Bead at the Centre of the Teſt.

Gold and Silver Ores, how treated in the large Way.

9. In the large Way of Buſineſs, Silver or Gold Ores are treated either by Amalgamation with Mercury, or by Smelting and refining them with Lead. The Method by Amalgamation is

uſed only where the Ore is exceeding rich; particularly at the Silver Mines of *Potoſi*: For by grinding ſuch rich Ores with Mercury, the nobler Metals will be drunk up by it, and may be readily ſeparated from it again by Diſtillation, which carries over the Quickſilver, and leaves the nobler Metals behind. Lead is uſed along with the poorer Ores, in order to drink up the nobler Metals they may contain; which it does much after the ſame Manner by Fuſion, as Quickſilver does without it; ſo as to ſeparate many heterogeneous Parts, by keeping them floating, and afterwards reſtoring the nobler Metals, by Cupellation.

By Amalgamation.

10. The large Way of Smelting Gold and Silver Ores is analogous to the ſmall one of Aſſaying; all things being proportionably larger, the Fire animated with Bellows, and the Blaſt directed upon the Surface of the melted Metal; ſo as to blow off the Lead in the Form of Litharge, before it is fully vitrified. But here the Silver is not perfectly refined at one Operation; ſome Proportion of Lead ſtill remaining mixed among it, that requires to be burnt out, after the ſame Manner, in a ſtronger Fire: And even thus it is with great Difficulty that Silver can be obtained pure, or totally ſeparated, either from Lead or Copper. This large Way of working might perhaps be improved in reſpect of the Veſſel or Teſt employed, and the Management of the Fire; ſo as to work by the Means of Flame, without the Aſſiſtance of Bellows.

And Fuſion.

11. With regard to the Teſt, we are to obſerve that Bone-Aſhes, though ever ſo well waſhed and ſifted, are not, perhaps, the fitteſt matter to make Teſts of; the Teſts ſo made being apt to crack in the Fire, unleſs dried very gently for many Days before they are uſed. But there

The larger Operation improveable in the Teſt.

is a particular Kind of Talc, or unvitrifiable Spath-Stone, that being calcined to fine Powder, as it readily may, and made up with a ſmall Solution of Vitriol in Water, affords ſuch Teſts as may be immediately uſed without Danger of cracking.

And the Fire. 12. Again; the Flame of a Wind-Furnace may be made to play upon the Surface of the melted Metal; ſo as readily to perform this Operation, without the Uſe of Bellows, which violently tear away the Silver along with the Lead, in the Form of Litharge. And this farther Convenience may be obtained, that not only ſmaller and cheaper Wood, but even Pit-Coal ſhall here ſerve for the Fewel; provided the Structure of the Furnace be contrived for the Purpoſe. And in ſome Places they have of late advantageouſly uſed common Pit-Coal for Teſting in the large Way; and the ſame Improvements might alſo be made in the ſmall Way of Aſſaying.

Aſſaying imperfect. 13. But how improveable ſoever the Buſineſs of Aſſaying may be, it is ſcarce worth while to intimate in what Particulars it might be improved; becauſe the Aſſay-Maſters in all Countries are obliged to make their Aſſays in the Manner peculiar to each Country: Whence we ſee one Reaſon of the Diſagreements, ſo frequently complained of by Merchants, in the Aſſays made upon the ſame Kinds of Ore, in *Holland*, *Germany*, *England*, *France*, &c. The Methods employed for this Purpoſe all over *Europe* are, however, in moſt Reſpects the ſame; but ſhould never be truſted, unleſs two or three Experiments at leaſt, made at the ſame Time, by the ſame Perſon, agree in the ſame Report.

14. And perhaps in all Natural Philoſophy, Chemiſtry, and Metallurgy, there are no Experiments which require greater Skill, Accuracy, and Truth of Work, than thoſe in the Art of Aſſaying, to make them fit to be depended upon: Nor indeed can ſuch Preciſion as is here required be well expected, but from thoſe who are acquainted with the rapacious Nature of many volatile mineral Fumes, and the Methods of fixing them, or preventing their carrying off the nobler Metals upon the Teſt. To aſſay in Perfection alſo requires a Knowledge of the Relation and Differences of all the Metals with regard to each other; and particularly to Lead and Antimony. As this Art therefore requires ſo much Knowledge, and ſo much Accuracy, in order to practiſe it with Succeſs; hence, doubtleſs, proceeds the Difficulty we find in procuring a true Eſſay to be made upon any uncommon Ore: For the Art of Aſſaying is extremely backward in admitting of Improvements; as if it were to deſcend unaltered from one Generation to another.

Its Difficulty.

EXPERIMENT II.

The Method of ſeparating Gold from Silver, by Quartation.

15. We took a mixed Maſs of Gold and Silver, and melting it along with three or four times its own Weight of pure Silver, we beat the whole Lump, when cold, into a thin Plate; which we put into a Glaſs of Proof *Aqua fortis* *, ſet in warm Sand; whereby the Silver was ſoon diſſolved, and the Gold let fall in a black Powder

Gold ſeparated from Silver by Aqua fortis.

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* See *Lect.* VI. *Exp.* VI.

to the Bottom. The Solution of Silver we now carefully poured off, and adding a little freſh *Aqua fortis* to the Gold, we uſed a ſomewhat ſtronger Heat than before, in order to diſſolve any remains of Silver from amongſt the Gold-Powder. Then the *Aqua fortis* being again decanted, we waſhed the Gold well, in ſeveral Parcels of fair Water. And now the Gold-Powder was put into a little Say-Cup, and placed under the Muffle in the Teſting-Furnace till it became yellow. It might otherwiſe have been melted with Borax; which brings it to its true Colour and Form. We afterwards weighed the Gold, to determine the Proportion it bore to the Silver. Laſtly, we precipitated the Silver out of the *Aqua fortis*, by ſuſpending a Copper-Plate therein; then waſhed the Calx, and reduced it to its metalline Form in the ſame Manner.

Rationale.

16. The Reaſon for adding three or four Times the Quantity of Silver, in Proportion to the mixed Maſs, is, for fear the Maſs ſhould contain too much Gold to be fit for the Operation; or to ſpread the Gold contained in the Maſs, and diffuſe it ſo thinly, that it may not defend the Silver, as it otherwiſe would do, from the action of the *Aqua fortis*. And from the proportion of this Addition it ſeems to be that the Operation is called *Quartation*.

The Trouble and Expence of the Operation.

17. This Method of ſeparating Gold and Silver was unknown to the Ancients; who therefore ſeparated Silver from Gold by Calcination; and ſo loſt all the Silver that was mixed with the Gold. And indeed the Method by *Quartation* is expenſive and laborious; ſo as not to be very advantageouſly practiſed in the large Way of Buſineſs; though the whole has been divided into ſuch a Number of Hands, as to make the ſeveral Parts come cheap: ſome Operators being

wholly employed in making the *Aqua fortis*; others in purifying it, or bringing it to *Proof*; others in laminating the Silver, and diſſolving it; others in ſeparating and reducing the Calx of the Gold; others in precipitating the Silver with Copper; and others again in ſeparating the Copper from the *Aqua fortis*. And thus the whole Operation has been found to anſwer, ſo long as about a Dram of Gold could be recovered from a Pound of Silver.

The Operation improved, or ſuperſeded.

18. But there are certain Workmen of late, who have a Method of ſeparating Gold from Silver to much greater Profit, without the Uſe of *Aqua fortis*, or *Aqua regia*; and that barely by a dexterous Application or Management of the Fire; at leaſt without any coſtly Additions. This Method is kept as a Secret, but may, perhaps, be no other than that publiſhed by M. *Homberg* a); which conſiſts in fluxing the mixed Maſs of Gold and Silver with equal Parts of rough Nitre and decrepitated Salt, placed at the Bottom, of the Melting-Pot. By this means the Operation, in the large Way, may be finiſhed in a Quarter of an Hour, the Gold falling to the Bottom, and leaving the Silver ſuſpended or detained in the Salts. Another Way of effecting this Separation may depend upon a dexterous Uſe of Sulphur, which has the Power of making Silver melt away from a metalline Mixture almoſt as eaſy as Lead b).

Gold, how to be obtained pure

19. But to obtain either Gold or Silver in abſolute Purity is no eaſy Taſk. For the common Uſes, indeed, the Methods above delivered may ſerve; but for the more curious chemical and philoſophical Purpoſes, better Ways than

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a) In the *French* Memoirs.

b) See below § 20.

are commonly known and practiſed ſhould be diſcovered. To refine Gold by melting and teſting it with Antimony, or Glaſs of Antimony, is generally, and even by the metallurgical Chemiſts, thought a perfect Way; but M. *Homberg* * has ſhewn, that even this Criterion, as alſo Quartation, Cupelling with Lead, Fluxing with Borax, *&c.* may fail, in Caſe the Gold be mixed with *Emery*, or poſſibly ſome other things. When Gold is *eager*, as the Workmen call it, that is, brittle, they hold it as a Secret to melt it with Mercury-Sublimate. But perhaps no Gold can be proved to be perfectly pure, till it has gone through all the trials hitherto known; or even ſome of a more curious Nature; particularly melting with crude Antimony, and afterwards cupelling the Regulus with Lead; and at laſt, fuſing it with Borax. Which Proceſs we recommend to thoſe who require Gold in abſolute Purity for any Standard, or very curious Operation.

Silver, how.

20. The Methods of obtaining Silver in Purity are various, and differ according to the Metal wherewith the Silver is mixed or alloyed. If Copper be the Alloy, the beſt and cheapeſt Way to puriſy the Silver is, to calcine it with half its Weight of common Sulphur; then melt the whole together; and throw into the Pot, at ſeveral Times a due Quantity of clean and new Filings of Iron, which will immediately draw the Sulphur from the Silver, and Form a *Scoria* at top, leaving the Silver free from Copper, Iron, or Sulphur at the Bottom.

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* See the *French* Memoirs.

EXPERIMENT III.

The general Method of Aſſaying and Smelting the impurer Metals; Copper, Tin, Lead, and Iron.

21. We took four Ounces of Lead-Ore reduced to Powder, and mixing it with an Ounce of the clean Filings of pure Iron, and half an Ounce of the Black Flux *, we melted them all together in a new Crucible ſet in a Wind Furnace. By this Means we found the Lead clearly ſeparated, in a Lump, at the Bottom of the Crucible, after it was taken out of the Fire and ſuffered to cool. *Lead-Ore aſſayed.*

22. The Method of thus working in Crucibles, and by the Help of Fluxes, is not only too ſmall, but alſo too chargeable, to anſwer in the large Way of Buſineſs: Nor is there any Occaſion for being confined to this Method; ſince Fuſion in a naked Fire, or in Contact with the burning Fewel, is found to act as a powerful Flux, and get the Metal out of its Ore with Advantage. Hence we every where find that Metals are ſmelted in open Furnaces with a naked Fire. And though this hath long been a general Practice, the phyſical Reaſon of it ſeems little known; inſomuch that nothing is found more wanting in Philoſophical Metallurgy, than the particular *Hiſtory of common Fuſion.* *How ſmelted in the open Fire.*

23. The Ores of Lead, Tin, Copper, and Iron, are all commonly fuſed in Contact with the Fewel of the Furnace; the prepared Ore being at firſt ſtratified, or intermixed with the Wood or Coals: Nor could theſe Ores be any other Way fuſed in a large Quantity, ſo as *The* Rationale.

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* See *Lect.* I. *Exp.* II.

to acquire a metalline Form, though urged with ever ſo ſtrong a Flame, or beat ever ſo violently upon by the Fire, while kept from touching the Coals, by being included in a large Crucible, or Melting Pot, after the Manner that Glaſs is made; or without adding ſome Flux-Powder, of an oily or inflammable Nature [a]). Even if the Ore thus treated were rich, or naturally contained ſome viſible Grains of pure Metal, this Metal would only remain in almoſt the ſame State as it was, without enlarging its bulk from the Reſt of the Ore: Whereas if a little powdered Charcoal be thrown in, or the Ores be committed to a naked Wood-Fire, they preſently reſolve into Metal.

The metallic Nature how preſerved, or recovered.

24. We might obſerve in our Experiment of Cupellation [b]), how extremely apt theſe imperfect Metals are to receive a deſtructive Alteration in the Fire, or to be burnt and reduced to Aſhes, or Glaſs, along with the Lead; on which Diſpoſition of theirs the Art of Cupelling depends. But by contriving to melt theſe Metals in Contact with the Coals, their metallic Form is greatly preſerved; eſpecially as the ſtony, vitrifiable Matter, wherewith ſuch Ores are uſually mixed, occaſions them, by their clinging Nature, to unite more intimately with the glowing Coals.

Metalline Calces reduced.

25. This Doctrine receives a remarkable Confirmation from the uſual Method of recovering Metals burnt to Aſhes at the Smelting-Furnace: For if the Litharge, blown off in teſting, or even the Glaſs of Lead, or the Aſhes of any other of the imperfect Metals, be barely melted in Contact with Charcoal, they preſently recover their metalline Form. And the ſame Thing

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[a]) See *Lect.* II. *paſſim.*

[b]) See *Exp.* I.

is likewiſe effected by the Addition of any unctuous or inflammable Matter; whence it ſeems to be the unctuous or inflammable Matter of the Coals, which thus inſinuating into the metalline Calces, reſtores their metallic Nature. And we have ſeveral Times, in the Courſe of theſe Lectures, had Occaſion to obſerve the great Affinity there is betwixt Oils and Metals *; inſomuch that their true metallic Form, or their Softneſs and Ductility, ſeems entirely owing thereto.

Three things to be regarded in Fuſion;

26. There are three Things, therefore, to be principally regarded in the Smelting of Ores; *viz.* (1) the Fuſibility of the Metal; (2) the Fuſibility of the *Scoria*; and (3) the Contact or Mixture of the metallic Matter with the inflammable Part of the Coals.

viz *The Fuſibility of the Metal:* In*ſtanced in Lead.*

27. (1) Different Metals run in different Manners from their Ores. Thus Lead, though extremely fuſible in the Metal, yet runs with Difficulty from the Ore; ſo as to require a conſiderable Violence of Fire. This Stubbornneſs, not belonging to the Metal, muſt be attributed to the ſtony, ſulphureous, or other mineral Matter, wherewith the Ore is mixed; which Matter ſeems to require a Degree of Heat capable of vitrifying the Lead, before the Metal will run: But then the Lead thus vitrified recovers a metallic Form again, by coming in Contact with the Coals.

28. In the Caſe of our preſent Experiment, the Iron-Filings laying hold of the ſulphureous Parts of the Ore, leave the Lead at Liberty to run much ſooner, and freer, from the Stone: Where alſo the great Degree of Heat communicated by the Iron-Filings, and their inflammable Nature, muſt have a conſiderable Effect, at the

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* See *Lect.* VI. *Exp.* II. *& alibi paſſim.*

ſame Time that they will not incorporate with Lead, but float on its Surface in Fuſion.

Tin, Copper, and Iron.

29. Tin runs from its Ore with greater Eaſe than Lead; and is therefore ſmelted in much leſs Furnaces: But Copper requires an intenſe Heat, or a Blaſt-Furnace; and Iron, the greateſt Heat that can be given in a Furnace: and both Iron and Copper abſolutely require immediate Contact with the Fewel employed. Hence it appears, that each Metal muſt have its determinate Degree of Heat, to run it with Advantage from the Ore or Stone.

The Fuſibility of the Slag.

30. (2) In order, likewiſe, to obtain the Metal from the Ore to beſt Advantage, the *Scoria*, or Slag, muſt be neceſſarily made to run thin and fluid; otherwiſe it entangles or inviſcates the Metal, and will not let it ſeparate fully. And hence we frequently obſerve, in the Aſſaying of Copper Ores, ſmall grains of Metal interſperſed, here and there, among the *Scoria*, that require to be ſeparated by ſtamping and waſhing the whole Maſs; which Labour might have been prevented, by uſing a ſuitable Flux, and a proper Degree of Heat, capable of procuring a thin Fuſion; ſo as to have made all the Metal fall to the Bottom of the Crucible, which it conſtantly does when the Operation is well performed.

31. To promote a thin Fuſion of the Slag, in the larger Furnace, it is often proper to uſe the more ſoft and fuſible Sands as a Flux; and ſometimes that Loamy Sand, which the Smiths employ for the Welding of Iron; this Sand readily vitrifying, and adhering to the Metal in the Fire: And where it will anſwer the Charge, even Litharge, or Droſs of Lead, might be uſed for this Purpoſe, in the larger Furnaces; for ſcarce any Thing procures ſo thin a Fuſion of the Slag.

32. In the large Work, Sulphur is ſound to adhere tenaciouſly to Copper; which Metal, therefore, ſeldom comes out pure in the Furnace, without repeated Fuſions. The beſt Method of ſeparating this Sulphur is, to uſe a violent Heat, no additional Flux at all, and the greateſt Draught of Air that can any Way be procured; ſo that all Things may conſpire to burn out, or carry off, the Sulphur, and introduce, in its Stead, a Thing of a different Nature; *viz.* the inflammable Matter of the Coals; on which, as we before obſerved, Ductility ſeems to depend. But where Iron is mixed with Copper, no better Addition is found than Sulphur, and the more ſulphureous Marcaſites; or what at the Smelting Huts they call *Marcaſite Blocks*: For the Sulphur which theſe contain cauſes the Copper readily to run away from the Iron, and leave it behind in the Furnace. And here the Power which Sulphur has upon the ſeveral Metals is very remarkable. We before obſerved, that it renders Silver almoſt as fuſible as Lead *: It alſo greatly increaſes the Fuſibility of Iron, and Regulus of Antimony; but renders Tin much leſs fuſible than it is of itſelf; and Lead, even refractory in the Fire: Whence certain Rules might be formed, for the Uſe and Application of Sulphur to Metals, for the Improvement of Metallurgy. And thus the whole Art of Smelting ſeems to depend upon knowing the Degree of Heat required by every Ore; ſo as to make the Slag, as well as the Metal, run thin, and evaporate or diſcharge the ſulphureous Parts; and, laſtly, to introduce the proper

Sulphur how ſeparated from Copper.

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* *Exp.* II. §. 18.

metallic, ductile Form, by Means of an unctuous or inflammable Matter.

Conſequences of inartificial Fuſions and Separations.

33. It ſeems principally owing to a Defect in the Knowledge of Fuſion, that ſo many Recrements, or Slags, of Metals, anciently thrown, as uſeleſs, from the Furnace, have been wrought to conſiderable Profit of late, by more ſkilful Workmen; at leaſt it ſeems more rational to attribute the Succeſs to this Cauſe, than to any ſuppoſed Growth of Metals in ſuch Slags: So likewiſe it is currently believed, that Lead grows rich in Silver, by lying expoſed to the open Air, or by long covering Churches, or other Buildings; whilſt perhaps it is rather owing to the Unſkilfulneſs of the former Workmen, who were not able to ſeparate all the Silver naturally contained in Lead. And thus it appears certain, that the ancient Metallurgiſts were unacquainted with any Way of extracting, to profit, a ſmall Quantity of Silver out of Copper; which is now commonly done by an ingenious Contrivance *: Whence the ancient Copper found upon Temples, or other Buildings, frequently contains Silver. So likewiſe in the *Foreſt of Dean* they at this Day work the Slag of their old Iron-Works over again to Profit.

Metals to be carefully cooled.

34. All Moiſture, as well as too ſudden Cooling, proves prejudicial to the more ignoble Metals after Fuſion; and ſometimes dangerous to the Operator. A little Water falling upon melted Iron or Copper makes them expand with prodigious Violence, and diſcharge themſelves abroad with a Force like that of a Canon: And even ſudden cooling will often occaſion the Surface of the Metal to crack, and force the more internal Part, not yet ſet or fixed, to iſſue out to

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* See below, §. 35.

a conſiderable Diſtance; whence either Loſs of the Metal or Miſchief may enſue. But to prevent theſe ill Effects, after Cupellation, it is uſual for the Operator to throw a Quantity of Water, all at once, upon the Lump of Silver, as it lies in the Teſt, at the Moment that it begins to grow rigid; for thus the Water, by its Coldneſs, ſuddenly makes ſo thick a Cover upon the Surface of the Silver, that the hotter inſide Parts cannot break through the upper: Whence that ſpringing, or ſpouting out, of the Silver, which we ſometimes ſee in the ſmaller Way of aſſaying upon the Teſt, when the Metal ſpontaneouſly cools, is entirely prevented.

The ignobler Metals how ſeparated from each other; viz. *Iron from Copper.*

35. We have already conſidered how Gold and Silver are to be ſeparated when mixed *a*); we ſhould alſo know how the leſs noble Metals may be ſeparated from one another: This is done either by Means of Fire alone, or by Means of Lead. Thus Copper, being more fuſible than Iron, will, in a proper Furnace, melt, and run entirely from it; whilſt the Iron is not made to flow with the ſame Degree of Heat as melts the Copper, or elſe ſticks behind in the Slag. After the ſame Manner Lead, being more fuſible than Copper, readily runs away from it, in a Furnace kept of a due Heat for the Purpoſe. A Mixture of Iron and Lead is ſeparated in the ſame Manner; the Iron floating upon the Surface of the Lead. Copper, Tin, Iron, Antimony, *&c.* we before obſerved might be ſeparated from Gold or Silver, by teſting with Lead *b*); but then the ignobler Metals are loſt. And where only a ſmall Proportion of Silver is mixed with a large one of Copper, this Method would prove uſeleſs, or prejudicial:

Lead from Copper.

Iron from Lead.

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a) See *Exp.* II. *b*) *Exp.* I.

Silver from Copper. Nor can a ſmall Proportion of Silver be well ſeparated from Copper, by any Method hitherto known; ſo as to preſerve the Copper pure, or eaſily recoverable: Whence at the Smelting-Huts the Method is, to get the Silver out of imperfect Copper, whilſt it ſtill remains mixed with its own Sulphur, under the Form of what they call *Black Copper*. This they melt, and make to run among a large Proportion of melted Lead; then caſting the Mixture out into large Blocks, theſe are carried to a particular Furnace, and there ſet upright, ſo as that the Fire, being lighted at top, may commodiouſly play between them. And thus the Lead melts away from the Blocks, carrying with it the Silver before contained in the Copper; the Blocks of which Metal are now left hollow, porous, ſpungy, and wrinkled. Theſe exhauſted Blocks are then removed to a hotter Furnace, in order to be farther drained of their Lead. The laſt Remains are now, in another Furnace, reduced to perfect Copper; and the whole Parcel of Lead, thus enriched, committed to the Teſt, in order to ſeparate the Silver.

Copper Ore teſted. 36. In the ſame Manner may Copper Ores be aſſayed, by teſting them with a ſmaller Proportion of Lead than is uſed to Silver Ores; tho' this Operation requires a great Degree of Care and Exactneſs, to prevent the Copper from being carried off with the Lead, or vitrified. So likewiſe when Copper happens to be mixed with Iron, the beſt Method of ſeparating them, in the Way of Eſſay, is to melt them with Lead; which readily imbibes the Copper, but throws the Iron to the Surface; where being entangled with the vitrified *Scoria* of the Lead, it may be taken off, and the Copper thus brought to a great Degree of Purity; though indeed it is apt to loſe a little of its Ductility, on Account of ſome very minute Proportion of Lead, or its Fumes, remaining therein.

The Doctrine general.

37. We have not here confined ourſelves to the Conſideration of one Metal more than another; but endeavoured, under the preſent Experiment, to ſhew the Ways of treating all the ignobler Kinds, or working them, in the beſt Manner, from their Ores. It is eaſy to apply this general Doctrine, occaſionally, to the Treatment either of Lead, Tin, Copper, or Iron.

EXPERIMENT IV.

The Method of making Prince's Metal.

A mixed Metal of Copper and Zink.

38. We took ſix Ounces of Copper, and melting it in a Wind-Furnace, added to it an Ounce of Zink; then ſtirring the whole well together, we immediately poured out the Metal. The Copper and the Zink may be put into the Crucible together, if firſt covered over with the Black Flux; which prevents the Avolation of the Zink, or preſerves its metalline Form.

Braſs how made.

39. This is an expeditious Method of making a fine Kind of Braſs; whereas the common Method with *Lapis Calaminaris* requires a conſiderable Length of Time, and a violent Fire: For this Purpoſe they calcine and powder the Calamy; then mix it with a little Charcoal-duſt; and to ſeven Pounds of this Mixture add five of Copper-Plates; then giving eleven or twelve Hours Fire, the Copper imbibes about one third of its Weight of the Calamy.

The Nature of Calamy.

40. It is here remarkable that the Calamy, though no compleat metallic Body, nor malleable, ſhould yet concrete along with the Copper, ſo as not only to increaſe its Weight, but alſo to

extend with it under the Hammer; which Zink, in making the Prince's Metal, does not do, though it appear in all Reſpects of a more metallic Nature than Calamy.

And Zink. 41. The Agreements and Diſagreements of theſe two Bodies, Zink and *Lapis Calaminaris*, may deſerve to be farther enquired into, by particular Experiments. The Inflammability of Zink is very remarkable; for it burns durably of a bluiſh white Flame in the Fire; and thus reſolves into a white Calx.

Imitations of Gold. 42. Many curious Phænomena, and unexpected Reſults, happen upon mixing metallic and mineral Bodies in the Fire; all which deſerve to be tried, and noted, as Facts that might at leaſt direct to the diſcovery of ſeveral new and uſeful Mixtures, or Compoſitions of Metals. We might be encouraged to proſecute this Enquiry, by thoſe pretty Imitations of Gold, lately introduced for the making of Watches, Buckles, Cane-heads, Snuff-boxes, &c. But perhaps a better Imitation of Gold, for theſe and many other Purpoſes, may be obtained by M. *Homberg*'s Method of treating Copper with Quickſilver: For if an Amalgam be made of one Part pure Copper, and three Parts Quickſilver; and the Amalgam be boiled in River-Water for two Hours; then the Quickſilver diſtilled off, and cohobated once; the remaining Copper, being now fuſed, will be found of a beautiful Gold Colour, and more ductile than common Copper; ſo as to become well fitted for Watch-work, Gilding, and the finer Machines and Utenſils.

Homberg'*s. Metal.*

EXPERIMENT V.

The Method of converting Iron into Steel.

43. We took a few Pieces of ſoft Iron-Wire, and burying them in a cloſe Crucible, full of powdered Charcoal, ſet the whole in a Wind-Furnace, for two or three Hours; then taking out the Pieces of Wire we found them changed to Steel. *Steelmade.*

44. The Method of making Steel has been uſually kept as a Secret, and at preſent there are but very few Steel-makers in *England*: The ancient Method was, to keep ſlender Bars of Iron ignited, for ſeveral Hours, in a melted Mixture of Iron and vitreſcible Sand; then taking out the Bars, forging them, and immediately plunging them, whilſt hot, into cold Water; afterwards forging them again, till they would eaſily ſnap, and appear white, and of a cloſe Texture, or Steel-Grain, when broke. *The ancient Method.*

45. The preſent Method is, to ſtratify a large Number of ſlender Iron Bars with powdered Charcoal; to fill a Furnace with them, in the Form of a long Cheſt; and then to keep up a ſtrong Fire, but ſo as not to melt the Iron, for two or three Days together. And thus at length, when the Furnace is cold, the Bars are taken out unaltered in their external Form: But they may be bliſtered according to the Pleaſure of the Operator, by uſing Quicklime along with the powdered Charcoal. *The modern Method.*

46. The whole Secret of making Steel ſeems to depend upon excluding the Air from the Iron to be wrought upon. Accordingly if a large Ball of Iron be kept ſo hot, for ſome Time, that its external Surface ſhall melt, and run like Water, *On what the Operation depends.*

Water, the internal Part of the Ball will, at the ſame Time, be converted into true Steel. And hence appears the Reaſon why certain Knots, or Spindles, of Iron are ſometimes found in the Middle of Caſt-Work, ſo hard that no Tool will touch them.

Caſe-hardening.

47. The Art of Caſe-hardening is a leſſer Degree of Steel-making; and is practiſed by baking Raſors, Files, Knife-Blades, *&c.* in a Kind of Oven, ſtratified with powdered Charcoal, Hoofs, Horns, and the like, ſo as to exclude the Air; and thus, by baking, to give a Coat of Steel to Inſtruments, ſome Depth below their Surface.

The beſt Steel, how made.

48. But the Making of the beſt Steel depends upon the Nature of the Iron employed, or its Ore; and uſually requires a proper Mixture of ſeveral Kinds together, as well as Perfection in the Art of Tempering; which, according as it is managed, ſuits the Steel for different Uſes. Thus Gravers are of one Temper, Drills of another, Watch-Springs of another, Razors of another, *&c.* Which Tempers are given them by being quenched with different Heats in Tallow, Water, or certain Liquors, Juices, or the like.

AXIOMS *and* CANONS.

1. We learn from the foregoing Enquiry, That different mineral and metallic Matters bear different Relations to melted Lead in Fuſion: Whence ſome of them will not mix therewith, but float on its Surface; others evaporate, and others vitrify with it; whilſt Silver and Gold remain unaltered by it, and unimpaired *.

2. That the nobler Metals have nearly the ſame Relation to Quickſilver, as they have to

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* *Exp.* I.

melted Lead; being readily drunk up by them both, and thus ſeparated from other heterogeneous Matters *a*).

3. That Teſting, in the large Way, is improveable by finding a properer Matter than Bone-Aſhes for the making of Teſts; by working without Bellows; and again by uſing Pit-Coal, and a well contrived Furnace *a*).

4. That the Art of Aſſaying is hitherto imperfect; but capable of receiving conſiderable Improvements from chemical and mechanical Knowledge *a*).

5. That the troubleſome and expenſive Method of ſeparating Gold from Silver by *Quartation*, may be advantageouſly ſuperſeded, or ſet aſide, by Means of Fuſion, or a dexterous Management of the Fire *b*).

6. That Gold and Silver are rarely rendered abſolutely pure, or ſeparated from all other Kinds of metallic or mineral Matters; and that to purify them to ſuch a Degree requires the Uſe of better Methods than thoſe commonly employed: though the Thing is ſtill performable by Art, and a ſuitable Proceſs *b*).

7. That the particular *Hiſtory of common metallic Fuſion* is wanting, for the Improvement of Metallurgy *c*).

8 That when the Ore of an imperfect Metal is in immediate Contact with the Fire or Fewel, it yields more and better Metal, than when contained in a Crucible, or kept from touching the Coals *c*).

9. That a languid Fire leſſens the Yield of an Ore; but a briſk one, if not too long continued, increaſes it *d*).

a) *Exp.* I. *b*) *Exp.* II. *c*) *Exp.* III. *d*) Ibid. See alſo *Lect.* XVII.

10. That the Buſineſs of Smelting in Perfection depends (1) upon uſing a Degree of Fire ſuited to the Ore; (2) procuring a quick and thin Fuſion of the *Scoria*; and (3) a cloſe Contact of the Metal with the Fewel, or Coals, employed *a*).

11. That Sulphur has different Effects upon the different Metals; which Effects being well noted, Rules of Practice might be thence derived, for the farther Improvement of Metallurgy *a*).

12. That metalline Recrements, or the Slags of Metals once ſmelted, have been wrought over again to profit, on Account of the imperfect Manner wherein the Ores were originally treated for their Metals *a*).

13. That the ignobler Metals are ſeparable from each other by the Application of proper Degrees of Heat; ſo as to make the more fuſible melt away from the leſs fuſible; at leaſt with the Aſſiſtance of Lead *a*).

14. That all Metals are reducible, by burning, or Calcination, to terreſtrial Powders, or *Calces*; which, by being melted with any inflammable Matter, aſſume their metalline Form again *a*).

15 That the great Enemies to Ductility, or the true metallic Nature, are Sulphur, Cobalt, and Things compounded thereof *b*); but that all unctuous or inflammable Bodies are friendly to Metals, and promote or reſtore their Ductility, when melted therewith *c*).

16. That Copper may be made to approach the Colour of Gold, and at the ſame Time not loſe, but increaſe, its Ductility, by being amalgamated with, and diſtilled from, Quickſilver;

a) *Exp.* III. *b*) *Exp.* III. See alſo *Lect.* XVII. *c*) *Exp.* III.

and that probably many artificial or compound Metals are diſcoverable, by mixing various metalline and mineral Bodies together; ſo as greatly to enrich and improve the Art of Metallurgy *a*).

17. That Steel is made by a proper Application of Fire to Iron, in a cloſe Place, ſo as to prevent the open Air from communicating freely with the Iron *b*).

18. That Metals receive particular Alterations in their Texture or Conſiſtence, according to the Nature of the ſolid Subſtance or Liquor, wherein they are quenched or cooled *b*).

19. That, in general, Ores are no more than a natural, looſe Mixture of metallic Matters, along with earthy and ſulphureous ones: Whence artificial Ores may be readily made, by calcining a Metal with Sulphur, and mixing it with Earth; ſo as, with Heat, to form ſolid Lumps of Ore, reſembling thoſe Dug out of Mines *c*).

20. That numerous Experiments remain to be made, Facts of Nature, or Obſervations, to be regiſtered, and Relations of Bodies to be found, before this uſeful Subject of Metallurgy can be brought to Perfection *d*).

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a) *Exp.* IV. *b*) *Exp.* V. *c*) See *Lect.* XVII. and XVIII. *paſſim.* *d*) *Exp.* I. II. III. IV. V.

LECTURE XIX.

CONTAINING

PYROTECHNY; *or Experiments relating to* Gunpowder, Exploſions, *and* Phoſphori.

The Deſign. 1. THE preſent Deſign is to enquire into the Nature of Gunpowder, Exploſions, and *Phoſphori*; and to try if any uſeful Doctrine or Diſcoveries may be thence derived, for the Improvement of Chemiſtry and Natural Philoſophy. We therefore propoſe (1) to examine into the Nature and Compoſition of Gunpowder, with the Ways of trying and improving it; (2) to ſhew ſome of the more remarkable Kinds of Exploſions; (3) to examine ſome of the more eminent *Phoſphori*; and (4) to deliver the Doctrine pointed out by this Kind of Experiments.

The Intent of the Experiments. 2. Our *firſt* Experiment, therefore, will ſhew the Method of making Gunpowder; our *ſecond* the Method of making the *Pulvis* and *Aurum fulminans*; our *third*, a Method of producing Heat and Fire by the Mixture of Sulphur and Iron Filings; our *fourth*, a Method of producing Coruſcations with Oil of Vitriol and Iron Filings; our *fifth*, a Method of producing Fire and Flame by the Mixture of two cold Liquors; and our *ſixth* Experiment will ſhew the Method of making the liquid Phoſphorus of Urine.

EXPERIMENT I.

The Method of making Gunpowder.

Gunpowder made.

1. We took four Ounces of refined Salt-Petre, an Ounce of Brimſtone, and ſix Drams of Small-Coal; theſe we reduced to fine Powder, and continued beating them, for ſome Time, in a Stone-Mortar, with a Wooden Peſtle; wetting the Mixture, between whiles, with Water, ſo as to bring the whole into an uniform Paſte; which we then reduced to Grains, by paſſing it through a Wire-Sieve fit for the Purpoſe: And in this Form, being carefully dried, it became the common Gunpowder.

Nitre how pulverized readily.

2. We formerly ſhewed the Way of refining Salt-Petre for the making of Gunpowder *. In order to reduce this Salt to Powder, they diſſolve a large Quantity of it in as ſmall a Proportion of Water as poſſible; then keeping it continually ſtirring over the Fire, till the Water exhales, a white dry Powder is left behind.

The Sulphur purified.

3. In order to purify the Brimſtone employed, they diſſolve it with a very gentle Heat; then ſcum and paſs it through a double Strainer. If the Brimſtone ſhould happen to take Fire in the melting, they have an Iron-Cover that fits on cloſe to the melting Veſſel, and damps the Flame. The Brimſtone is judged to be ſufficiently refined, if being put between two hot Iron Plates, it melts into a Kind of red Subſtance, without yielding any fetid Odour.

The Coal prepared.

4. The Coal for the making of Gunpowder, is either of Willow or Hazel, well charred in the uſual Manner, and reduced to Powder: And thus the Ingredients are prepared for mak-

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* See *Lect.* XIII.

The Stamping. ing this Commodity. But as theſe Ingredients require to be intimately mixed, and as there would be Danger of their firing if beat in a dry Form, the Method is to keep them continually moiſt, either with Water, Urine, or a Solution of Sal-Ammoniac, and to continue thus ſtamping them together for 24 Hours; after which the Maſs is fit for corning, and drying in the Sun or otherwiſe, ſo as ſeduloufly to prevent its firing.

Rationale *of Gunpowder.* 5. The exploſive Force of Gunpowder is now a thing commonly known; but the phyſical Reaſon thereof may not, perhaps, be hitherto ſufficiently underſtood. In order to explain it, let us obſerve (1) that Salt-Petre, of itſelf, is not inflammable; and though it melts in the Fire, and grows red hot, yet it does not explode, unleſs it comes in immediate Contact with the Coals; (2) that Brimſtone eaſily melts at the Fire, and than readily catches Flame; (3) that powdered Charcoal readily takes Fire, even from the Sparks yielded by a Flint and Steel; (4) that if Nitre be mixed with powdered Charcoal, and brought in Contact with the Fire, it burns and flames; (5) that if Sulphur be mixed with powdered Charcoal, and Fire applied to it, part of the Sulphur burns ſlowly away, but not much of the Charcoal; and (6) that if a lighted Coal be applied to a Mixture of Nitre and Sulphur, the Sulphur preſently takes Fire, with ſome Degree of Exploſion, leaving a Part of the Nitre behind; as we ſee in making the *Sal Prunellæ* and *Sal Polychreſtum.*

6. Theſe Experiments duly conſidered may give us the chemical Cauſe of the ſtrange exploſive Force of Gunpowder: For each Grain of this Powder conſiſting of a certain Proportion of Sulphur, Nitre, and Coal, the Coal preſently

ly takes Fire, upon Contact of the ſmalleſt Spark; whereupon both the Sulphur and the Nitre immediately melt, by Means of the Coal interpoſed between them, and burſt into Flame; which, ſpreading from Grain to Grain, propagates the ſame Effect almoſt inſtantaneouſly; ſo that the whole Maſs of Powder comes to be fired: And as Nitre contains a large Proportion both of Air and Water, which are now violently rarefied by the Heat, a Kind of fiery exploſive Blaſt is thus produced; wherein the Nitre ſeems, by its aqueous and aerial Parts, to act as Bellows to the other inflammable Bodies, Sulphur and Coal, blow them into a Flame, and carry off their whole Subſtance in Smoak and Vapour.

Its Diſcovery.

7. The Diſcovery of this Compoſition was accidental, and perhaps owing to that common Operation of fulminating Nitre with Sulphur, for the making of *Sal Prunellæ.* It appears to have been known long before the Time of *Schwartz*, as being particularly mentioned by Friar *Bacon.*

The Ingredients differently proportioned.

8. The three Ingredients of Gunpowder are mixed in various Proportions, according as the Powder is intended for Muſquets, Great Guns, or Mortars: Though theſe Proportions ſeem not to be hitherto perfectly adjuſted, or ſettled by competent Experience.

How tried as to purity.

9. There are two general Methods of examining Gunpowder; one with regard to its Purity, the other with regard to its Strength. Its Purity is known, by laying two or three little Heaps near each other upon white Paper, and firing one of them; for if this takes Fire readily, and the Smoke riſes upright, without leaving any Droſs or feculent Matter behind, and without burning the Paper, or firing the other Heaps, it is eſteemed a Sign that the Sulphur and Nitre

were well purified; that the Coal was good; and all the three Ingredients were thoroughly incorporated together. But if the other Heaps alſo take Fire at the ſame Time, it is preſumed that either common Salt was mixed with the Nitre, or that the Coal was not well ground, or the whole Maſs not well beat and mixed together; and if the Nitre or Sulphur was not well purified, the Paper will be black or ſpotted.

How as to Strength. 10. In order to try the Strength of Gunpowder, there are two Kinds of Inſtruments in Uſe; but neither of them appear more exact than the common Method of trying to what Diſtance a certain Weight of Powder will throw a Ball from a Muſquet.

How ſtrengthened. 11. To increaſe the Strength of Powder, it ſeems proper to make the Grains conſiderably large, and to have it well ſifted from the ſmall Duſt. We ſee that Gunpowder reduced to Duſt has little exploſive Force; but when the Grains are large, the Flame of one Grain has a ready Paſſage to another, ſo that the whole Parcel may thus take Fire nearly at the ſame Time; otherwiſe much Force may be loſt, or many of the Grains go away, as Shot, unfired.

12. It ſhould alſo ſeem, that there are other Ways of increaſing the Strength of Powder; particularly by the Mixture of Salt of Tartar: But perhaps it may be improper to divulge any Thing of this Kind, as Gunpowder ſeems already ſufficiently deſtructive.

White Powder. 13. There has been much talk of a *white Powder*; which, if it anſwered the Character given it, might be a dangerous Thing: For 'tis pretended that this white Powder will throw a Ball as far as the Black, yet without making any Report. But none of the white Powder which we have ſeen anſwers this Character; being, as we apprehend, commonly made either with Touch-wood or Camphire, inſtead of Coal. The moſt dangerous white Powder, if it may be ſo called, is condenſed Air; which, though able to diſcharge a Ball, with great Force, to a conſiderable Diſtance, makes not a loud Report; eſpecially when not violently condenſed, as it need not be to have pernicious Effects.

14. And how far Wind-Guns are improveable, has not, perhaps, been well conſidered. Some of them we have ſeen diſcharge a great Number of Bullets ſucceſſively; even the laſt whereof would go through an Inch-Plank, at the Diſtance of ſeveral Yards: So that this Machine might anſwer the ſame End as a Muſquet. But whether it be practicable to make great Guns in the ſame Manner, is another Conſideration; and chiefly depends upon finding a Spring ſufficiently ſtrong to reſiſt the violent Force wherewith Air might be condenſed by the Uſe of a Winch, &c. *Wind-Guns.*

EXPERIMENT II.

The Pulvis *and* Aurum fulminans *prepared.*

15. We took three Ounces of purified Nitre, two Ounces of Salt of Tartar, and one Ounce of Brimſtone, and ground them well together in a Mortar; then putting a ſmall Quantity, as about half a Dram, of this Powder upon an Iron Plate, and placing it over a gentle Fire, as ſoon as the Powder juſt began to melt, it made a ſmart and loud Exploſion. **Pulvis fulminans** *prepared.*

16. The moſt philoſophical Way of accounting for this Effect of the *Pulvis fulminans*, is by ſuppoſing that the acid Spirits of the Nitre and *Its Effect accounted for.*

Sulphur, being looſened by the Heat, ruſh towards one another, and towards the Salt of Tartar, with ſo great a Violence, as, by the Shock, at once to turn the whole into Vapour and Fume.

Aurum fulminans *prepared.* 17. We diſſolved a few Grains of fine Gold in *Aqua-Regia*, precipitated the Solution with Salt of Tartar, and thus obtained a Powder, which we dried with a very gentle Heat. A ſingle Grain of this Powder being laid upon the point of a Knife, and held over a lighted Candle, preſently went off, with a very briſk and loud Report.

Its odd Properties. 18. This *Aurum fulminans* has other remarkable Properties; for (1) it does not, like the *Pulvis fulminans* and Gunpowder, require the Application of actual Fire to make it explode; but though prepared with two of the moſt fixed Bodies, Gold and Salt of Tartar, yet is ſo volatile as to fly off, and give this loud Report, with a leſs Degree of Heat than ſuffices to kindle any of the moſt inflammable Bodies; or even by being ſtrongly rubbed in a Mortar, or dried on a hot Furnace: (2) It exerts its exploſive Force *in vacuo*, as well as in the open Air; and when made to explode in the exhauſted Receiver, a fine Gold Duſt has been found ſticking to the Sides of the Glaſs. (3) The Addition of a little Brimſtone to this Powder takes away its fulminating Property; ſo that after having been melted therewith, the Gold is ſet looſe, and may be eaſily recovered, in its native form, by fluxing it with Borax.

The Rationale. 19. Hence it ſhould ſeem that the Body of the Gold in this Powder is ſubtilely divided by the Action and Interpoſition of the Parts of the compound Menſtruum; which Menſtruum being of an aqueous and aerial Nature, and its Parts cloſely wedged in betwixt the fine ponderous Parts of the Gold in the *Aurum fulminans*, when this Powder comes, any way, to feel ſuch a Degree of Heat as ſuffices ſtrongly to rarify and expand the aqueous and aerial Particles, they burſt with Violence from their Priſons, and ſcatter the duſty Particles of the Gold around.

EXPERIMENT III.

The Production of Heat and Fire, by the Mixture of Sulphur and Iron-Filings.

The firing Mixture of Iron and Sulphur explained.

20. We took two Pounds of clean Iron-Filings, and as much common Brimſtone, and beating them together for ſome Time, in a Mortar, with the Addition of Water, we brought the whole to a Kind of Paſte; which being cloſe preſt into an earthen Pot, and ſet in a Chimney, it in a ſhort Time begun to grow hot, and at Length took fire.

21. This Mixture never fails to take Fire, if the Quantity be large; but if it be ſmall, the Paſte only heats and cracks, in ſeveral Places, ſo that hot Vapours iſſue out thereat. But if the Heat continues ſufficiently long, the whole Maſs will be changed into one uniform Subſtance; which, being ground and boiled in Water, affords good Vitriol of Iron *: Whence it is manifeſt, that the Acid naturally contained in the Brimſtone enters the Body of the Iron, and diſſolves it. This Action may therefore be the Cauſe of the Effect; eſpecially if we conſider that Sulphur conſiſts of an unctuous or inflammable,

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* See below §. 26.

mable, as well as an acid Part: For this inflammable Part of the Sulphur, doubtleſs, takes Fire in the violent Conflict betwixt the Iron and the Acid of the Sulphur.

And applied.

22. This Experiment, if duly attended to and applied, may, in the uſual Way of Philoſophers, account for ſeveral Phænomena of Nature; ſuch as burning Mountains, ſubterraneous Fires, Earthquakes, hot Baths, &c. Thus, for inſtance, as there are large Quantities of Iron-Stone, and Sulphur, found in the Bowels of the Earth; as alſo Marcaſites, which are a Mixture of the two; when theſe come to be wet, as they may, on many Occaſions, with Water, 'tis eaſy to conceive, that they muſt heat, ſwell, ferment, explode, and yield a hot Steam or Vapour, which forcing its Way through certain Caverns of the Earth, ſhall produce Earthquakes, or violent Strugglings, of longer or ſhorter Duration, till the Force finds vent, or expires through ſome Cranny into the Atmoſphere. Sulphureous Vapours certainly abound in the Bowels of the Earth, and ferment, and conflict with Minerals, ſo as to take Fire, and make ſudden Coruſcations, or Exploſions; and if confined in the Caverns of the Earth, ſometimes burſt and ſhudder thoſe Caverns to Pieces. At which Time the hot Vapours, generated by the Exploſion, and expiring through the Pores of the Earth, may raiſe Tempeſts and Hurricanes, or make the Ground ſink into Chaſms, or the Sea boil up in certain Places. Theſe ſulphureous Vapours at other Times aſcending into the Atmoſphere, may there ferment along with other Matters, take Fire, and thus Occaſion Thunder, Lightning, the *Aurora Borealis*, and other fiery Meteors: At leaſt this ſeems one

probable Cauſe of ſuch Effects, and has a Foundation in Nature *.

EXPERIMENT IV.

Coruſcations produced by means of Oil of Vitriol and Iron.

Artificial Coruſcations. 23. We took a cut Body, capable of holding two or three Quarts; and put into it three Ounces of Oil of Vitriol, and twelve of common Water; then warming the Mixture a little, we threw in, at ſeveral Times, two Ounces, or more, of clean Iron-Filings; upon which an Ebullition, and white Vapours, aroſe; then preſenting a lighted Candle to the Mouth of the Body, the Vapour took Fire, and at the ſame Time afforded a bright Fulmination, or Flaſh like Lightning. The Candle being ſeveral Times applied, in the ſame Manner, afforded the like Coruſcation; during which we ſometimes found the Glaſs filled with a Flame that reached, and circulated, to the Bottom of the Liquor; and ſometimes the Flame only roſe into the Neck of the Glaſs.

Cautions. 24. This Experiment will not ſucceed, unleſs the Oil of Vitriol be largely diluted with Water, to make the Menſtruum fit for diſſolving the Metal. 'Tis alſo requiſite to heat the Liquor a little, in order to promote the Solution, that the Vapour may aſcend the freer: But if the Liquor be too hot, the Vapour will riſe too faſt; and ſo, when the Candle is applied, only take fire in the Neck of the Glaſs, without making any remarkable Fulmination.

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* See Sir *Iſaac Newton*'s *Queries*, at the End of his *Optics*; and M. *Lemery*'s Paper upon the Subject, in the *French Memoirs*.

Rationale. 25. This Experiment appears to have a great Affinity with the preceding, and to depend upon nearly the ſame Principle; the Oil of Vitriol being a very powerful Acid, correſponding to that of Brimſtone; and Iron, in itſelf, containing ſomething that is properly ſulphureous, or inflammable. It ſhould ſeem, however, that it is not the Sulphur of the Iron alone, but that ſome ſulphureous Part of the Oil of Vitriol alſo contributes to the Effect; for Spirit of Nitre, or *Aqua fortis*, being uſed in this Caſe, produce no Fulmination: But the Spirits of Salt, of Sulphur, and of Allum, which are all ſulphureous, have here the ſame Effect as Oil of Vitriol.

Diſcovery and Uſe. 26. The Experiment ſeems to have been accidentally diſcovered, by inadvertently approaching a Candle near the Mouth of the Glaſs, whilſt Iron was diſſolving in diluted Oil of Vitriol, in order to make the common Vitriol of Iron; for if what remains in the Glaſs after the Fulmination is over, be boiled, filtred, evaporated, and cryſtallized, it affords this Vitriol in great Perfection, like what we before obſerved of the Mixture of Iron-Filings and Sulphur *a*).

27. We would recommend it to the curious in Chemiſtry, to endeavour to collect, and, if poſſible, to condenſe, a Quantity of the ſulphureous Vapour generated in the preſent Experiment: For this Vapour has not the fetid Smell of Brimſtone; but is, perhaps, ſomewhat like that volatile, aerial Spirit, which gives Virtue to certain mineral Waters *b*).

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a) See above, §. 22.
b) See *Hoffman* of Mineral Waters.

EXPERI-

EXPERIMENT V.

Fire and Flame produced by the Mixture of two cold Liquors.

28. We took two Drams of ſtrong and freſh Spirit of Nitre, prepared with Oil of Vitriol, and putting it into a clean and dry four Ounce Gally-Pot, we ſet it under a Chimney; then immediately, and at once, poured to it a Dram of the true eſſential Oil of *Indian* Cloves; and there was inſtantly produced a loud Noiſe, a violent Conflict and Ebullition, with a conſiderable Flame; which being extinguiſhed, a reſinous Subſtance, or actual Roſin, was found at the Bottom of the Gally-Pot. *Oil of Cloves and Spirit of Nitre mixed.*

29. To render this Experiment ſafe, (1) it ought to be performed under a Chimney that may carry up the offenſive Vapour; (2) the Oil ſhould be poured from a Phial fixed at the end of a Stick, to prevent any of the fiery Matter from flying upon the Operator: And to render it ſucceſsful, (1) the Spirit of Nitre ſhould be ſtrong, and freſh drawn; (2) the Oil ſhould be genuine; (3) the Veſſel wherein the Mixture is made ſhould be perfectly clean, dry, and large enough to give the Matter room to ſwell; (4) the Oil ſhould be poured in at once, to make the more expeditious Mixture. *Cautions.*

30. This Experiment is neither confined to one certain Oil, nor to one certain Acid; the diſtilled Oil of Saſſafras, Guajacum, Box, *Jamaica* Pepper, Cinnamon, or even the empyreumatic Oils of Hartſhorn, Blood, *&c.* will ſerve the Purpoſe; or, in general, any thin, eſſential Oil, thickened with Balſam of Sulphur, *&c.* For ſome *Extended.*

ſome Degree of Thickneſs or Tenacity in the Oil ſeems a primary requiſite, to make it explode with Spirit of Nitre; and for acid Spirits, Oil of Vitriol, and moſt of the other acid Spirits highly rectified, will produce Flame with the aromatic *Indian* Oils, if unadulterated.

31. The Experiment is made to give the greater Surprize when Gunpowder is fired by pouring a cold Liquor upon it; for if Gunpowder were put to the Oil, this alſo would be fired, upon pouring in the Spirit of Nitre. Hence it may ſeem ſtrange that Camphire, which is an exceeding inflammable Subſtance, ſhould not take Fire when added to the Oil, and treated as the Gunpowder. The Reaſon ſeems to be, that Camphire contains an Acid; and therefore when diſſolved in the Oil, ſomewhat anticipates or leſſens the Force of the Spirit of Nitre that is afterwards applied; ſo that the Shock betwixt the two is not now great enough to produce Flame: For in the Shock, or violent Conflict betwixt a ſtrong Acid and a thick Oil, diveſted of Acid, the Fire and Flame in the Experiment appear to be produced.

And accounted for

Its Force in vacuo.

32. Nor is the Effect leſſened when the Experiment is performed *in vacuo*; where half a Dram of Oil of Carraway-Seeds, and a Dram of Spirit of Nitre, have made a Flaſh like Gunpowder, and burſt the exhauſted Receiver, a Glaſs ſix Inches wide, and eight deep *. This is a very extraordinary Effect; as differing from moſt other flaming Bodies, which rather deſtroy than generate Air: But here muſt be a large Quantity of Air, or ſomething of equal Force, generated by the exploding Mixture, in order to balance and over-power the external Preſſure;

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* See Sir *Iſaac Newton*'s *Queries* at the End of his *Optics.*

which in this Caſe was ſeveral hundred Weight. Hence it ſhould ſeem that the Force of our exploſive Mixture is much greater than that of Gunpowder; which will not explode *in vacuo*, nor, even with the Aſſiſtance of the Air, produce any thing like ſuch an Effect. It may therefore be worth conſidering, whether ſo great a Power could not be applied to ſome uſeful Purpoſe. The Mixture might be made cheap, by uſing any of the groſs and ponderous empyreumatic Oils, inſtead of the eſſential Kind.

EXPERIMENT VI.

The liquid Phoſphorus *of Urine.*

Solid Phoſphorus made harmleſs.

33. We took half a Dram of Camphire, and ground it in a Glaſs Mortar, with three Grains of the ſolid *Phoſphorus* of Urine; then added as much eſſential Oil of Cloves as ſerved to reduce the whole to a fluid Form. The Mixture thus made may be rubbed upon the Cloaths, the Hair, or the Hands, without Danger of burning *a*).

Hiſtory of Phoſphorus.

34. Chemiſtry hath ſcarce afforded any Thing more ſurprizing than the common *Phoſphorus*. To ſee Letters traced with this Matter become luminous in the dark, Images and the Bodies of Men to blaze with Light, and Abundance of the like Experiments performed by Means of *Phoſphorus*, made many Perſons curious to know how it was made *b*). The Preparation indeed ſeems even to this Day kept as a gainful Secret in few Hands, and the Matter is ſold at a very great Price; Whence we apprehend it would be of

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a) See below under § 43. No. 11.

b) See M. *Homberg*'s Papers on the Subject.

ſingular Service to Chemiſtry, to render this Commodity cheaper, and diſcover its farther Uſes.

35. With this view we ſhall here touch a little upon the Hiſtory of this *Phoſphorus*, commonly called *Kunckell*'s *Phoſphorus*, or the *Phoſphorus* of Urine. It was diſcovered by accident: One *Brand*, an obſcure Chemiſt of *Hamburgh*, ſtumbled upon it as he was ſearching after the Philoſophers Stone, which he firmly believed lay concealed in Urine. This Subject therefore he tortured a thouſand Ways; and at length, after a violent Diſtillation, found a ſhining Matter, ſince called *Phoſphorus*, in his Receiver. This Matter was ſhewn to Dr. *Kunckell*; but the Proceſs was concealed from him. Soon after this *Brand* died; and *Kunckell* reflecting that *Brand* worked wholly upon Urine, he continued to work upon the ſame Subject himſelf for four years together; and at length, in the year 1679, found the Thing he ſought after. Doctor *Kraft* has uſually paſt for the Inventor of this *Phoſphorus*, he being the firſt that carried it abroad: but he only diſtributed it for Dr. *Kunckell*, being at that Time unacquainted with the Preparation.

The ſolid Phoſphorus, how made.

36. The ſucceſsful Method of making it is this: Evaporate any Quantity of freſh Urine over a gentle Fire, to a black, and almoſt dry, Subſtance; then with two Pounds thereof thoroughly mix twice its Weight of fine Sand; put the Mixture into a ſtrong coated Retort of Stone; and, having poured a Quart or two of clear Water into a large Receiver with a long Neck, join it to the Retort, and work in a naked Fire; let the Heat be ſmall for the two firſt Hours; then increaſe it gradually to the utmoſt Violence: and thus continue for three or four

Hours ſucceſſively. At the Expiration of that time there will paſs into the Receiver a little Phlegm and volatile Salt, much black fetid Oil, and laſtly the Matter of the *Phoſphorus* in Form of white Clouds, which will either ſtick to the Sides of the Receiver like a fine yellow Skin, or fall to the Bottom in Form of a ſmall Sand. Now let the Fire go out; but take not away the Receiver before it is cold, for fear of ſetting the *Phoſphorus* on fire, by admitting the Air. To reduce theſe ſmall Grains into one Piece, put them into a little Tin Ingot-Mould, along with ſome Water; heat the Ingot, to make the Grains melt together; then add cold Water, till the Matter is congealed into one ſolid Stick, like Bees-Wax; which being cut into little Pieces fit to enter the Mouth of a Phial, may be preſerved by Water, and by keeping the Glaſs cloſe ſtopped. If the Glaſs be not kept ſtopped, the *Phoſphorus* will turn black on its Surface, and at length be ſpoiled.

37. The Cautions required to make the Proceſs ſucceed are, (1) to evaporate the Urine, while it is recent; (2) to prevent its boiling over, and ſo loſing the moſt unctuous Part; (3) to let the Matter afterwards Ferment in the cold: (4) to mix the black Matter with Sand, to prevent its melting and running together; (5) to uſe a Stone Retort, thoſe of Earth being too porous, and ſuffering the *Phoſphorus* to tranſude ſooner than paſs into the Receiver; (6) to have the Receiver very large, and with a very long neck, to prevent its breaking and over-heating, which would either evaporate the white Vapour wherein the *Phoſphorus* conſiſts, or elſe prevent its coagulating; (7) to put Water into the Receiver, for keeping it cool, and quenching the *Phoſphorus*, as it falls to the Bottom; (8) to *Cautions.*

(8) to make the Fire ſmall at firſt, that the Retort may be preſerved, and the black Matter gradually dried, which would otherwiſe ſwell, and come over in a black Froth; *Laſtly*, it is found neceſſary, that the Urine for the Operation be of ſuch as uſe Malt-Liquors, rather than Wine. All theſe Circumſtances being required for obtaining the *Phoſphorus* to advantage, no wonder if ſo many have miſcarried in their Attempts to make it.

The Proceſs ſhortened. 38. This Operation may be greatly ſhortened, by freezing and concentrating freſh Urine, afterwards evaporating it with care, and then digeſting it *per ſe* in the Manner above mentioned. When thoroughly digeſted, commit the Matter, in a large Quantity, to an Iron Pot, with an earthen Head, as the Chemiſts uſually do for making Spirits of Hartſhorn, or the Spirit and Salt of Urine. When all the Salt and Oil are thus obtained, let the *Caput mortuum* be taken out, and mixed with twice its own Weight of Alum. This Matter may now be put into a well coated Long-Neck, and worked with care in a Reverberatory Furnace, into very large Receivers, filled with Water, and connected to the Long-Necks by Adopters; the lower Ends whereof ſhould enter the Water, as in diſtilling Quickſilver, and the Operation be continued for eight or ten Hours. And this we apprehend to be the beſt Way hitherto known of procuring *Phoſphorus* to Advantage. Dr. *Wall* informs us that Mr. *Boyle*, concerned to find how ſmall a Proportion of *Phoſphorus* was afforded by Urine, deſired him to look out for another Subject that might afford it in greater Plenty. The Doctor afterwards cauſing a Piece of dry Matter to be dug up in the Fields where Night-men emptied their Carts, he obſerved a great Number of ſmall Particles of *Phoſphorus* therein. This Matter the Doctor immediately carried to Mr. *Boyle*, who ſet *Bilgar* the Chemiſt to work upon it: But he could obtain very little *Phoſphorus* from it, till another Material was added thereto in Diſtillation; and then he procured *Phoſphorus* in ſuch plenty that, ſelling large Quantities at ſix Guineas the Ounce, he ſoon became rich and left *England* *. The Matter which thus fixes and increaſes the *Phoſphorus*, we apprehend to be Alum; which is itſelf not only in ſome Meaſure prepared from Urine, but appears to afford the ſame Kind of Acid that *Phoſphorus* yields by burning. For upon its Analyſis, *Phoſphorus* appears to be a Compoſition of a ſtrong Acid and an inflammable Matter united, exactly in the Manner of common Brimſtone; whence it may not improperly be called an *animal Sulphur*: And accordingly, like common Brimſtone, it will burn under a Glaſs Bell, and afford Flowers which, by attracting the moiſture of the Air, become an acid Liquor like *Oleum Sulphuris per Campanam.*

Farther Uſes.

39. And in this Manner it has been uſed, ſo as to produce extraordinary Changes upon Metals, eſpecially in the philoſophical View; the Acid itſelf, even without Heat, proving a Menſtruum to perhaps all the Metals. But when this Acid is driven into the Pores of the Metal, by the Action of the Flame in burning the *Phoſphorus*, it ſeems productive of much greater Effects; as is known to thoſe acquainted with the ſublimer Metallurgy. And it is principally with a View of promoting this Kind of Experiments, that we have beſtowed ſo much of our Lecture upon facilitating the Method, and eaſing the Expence,

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* See the *Philoſophical Tranſactions.*

of preparing this *Phoſphorus*; which of all the Kinds hitherto diſcovered ſeems the moſt uſeful.

Other kinds of Phoſphori.

40. This *Phoſphorus* has been ſeveral Ways diſguiſed, ſo as to make it appear under various Forms; ſometimes as a Solid, ſometimes as a Liquid, ſometimes as an Ointment, ſometimes as a running Mercury. There are alſo others of different Kinds; of which we ſhall only mention two, both diſcovered by M. *Homberg*. The firſt is that uſually called the *Black Phoſphorus*, now commonly prepared with Alum and Wheat Flower, by taking four or five Parts of Alum to one of Wheat Flower, and calcining them together to a brown or blackiſh Maſs; which being powdered, is put into a Phial, looſely ſtopped with Paper, and ſet in a Sand-Heat, ſo as to continue glowing hot for ſome time; then the whole is removed from the Fire, ſuffered to cool gradually, and at laſt the Bottle is ſtopped cloſe. A little of this Powder being poured out of the Bottle, and expoſed to the open Air, immediately takes Fire, and appears like a glowing Coal. But the Powder muſt be freſh made, to have a ſtrong Effect; for the Sun's Rays, or the Moiſture of the Air, being gradually admitted to it, deſtroy its Virtue: whence it ought to be kept in a dark and dry Place. 'Tis remarkable of this *Phoſphorus*, that it may be made from almoſt any animal or vegetable Subſtance, inſtead of Wheat Flower; but that no Salt whatever can be ſubſtituted inſtead of Alum.

The black Phoſphorus.

The Phoſphorus of Sal-Ammoniac and Lime.

41. M. *Homberg*'s other *Phoſphorus* is made of one Part Sal-Ammoniac, and two Parts Lime ſlaked in the Air; theſe being mixed well together, a Crucible is to be filled with them, and ſet in a ſmall Fire of Fuſion; where, as ſoon as the Crucible becomes red hot, the Mixture will melt, and ſhould be ſtirred with an Iron Rod,

to prevent its running over. When the Matter is entirely fuſed, it may be poured into a Braſs Mortar; and when cold it will appear of a grey Colour, and almoſt as if it were vitrified. If now it be ſtruck with any hard Body, it appears as on Fire in the whole Extent of the Stroke; but the Matter being brittle, it may be proper for the Experiment's ſake, to dip little Bars of Iron, or Copper, into the melted Matter in the Crucible; for thus they will be enamelled, as it were, with the Matter; and theſe Bars may be ſtruck upon, ſo as commodiouſly to repeat the Experiment ſeveral Times before the Matter falls off. The Bars are to be kept in a dry Place, to prevent the *Phoſphorus* upon them from running by the Moiſture of the Air.

Diſcovery of Phoſphori *accidental.*

42. Both theſe *Phoſphori*, were diſcovered by Accident: The firſt was obtained by ſearching for a limpid Oil, from the common ſtercoraceous Matter, that ſhould fix Quickſilver; and the ſecond, by endeavouring to calcine Sal-Ammoniac with Lime, ſo as to render it fuſible like Wax; which end was obtained, but not the other.

43. There have been no very conſiderable Uſes of theſe two *Phoſphori* hitherto diſcovered; but the *Phoſphorus* of Urine has been employed for making many curious Experiments; a few whereof we ſhall here exhibit.

Experiments with the Phoſphorus of Urine.

(1) The Light of this *Phoſphorus* appears greater *in vacuo* than in the open Air.

(2) In hot weather it is obſerved to dart Flaſhes of Light through the Water wherein it is contained, ſo as exactly to reſemble Lightning; which thus darts unextinguiſhed through watery Clouds and Vapours.

(3) Theſe Flaſhes of Light are not apt to kindle or burn any combuſtible Matter, in which they reſemble the harmleſs Kind of Lightning; but in a condenſed State this *Phoſphorus* burns very furiouſly, and with a moſt penetrating Fire, ſo as to melt and diſſolve Metals: In which reſpect it again reſembles the more deſtructive Kinds of Lightning, which are found to have the ſame Effects.

(4) If a little Piece of this *Phoſphorus* be view-ed through a Microſcope, the internal Parts appear in a conſtant Ebullition.

(5) A little Piece of it being put into a Silver Spoon, and held over the Fire, it burſts out into a ſhining Flame, leaving a red ſpot in the Spoon of a corroſive, acid taſte; which being diluted with Water, the Mixture makes a conflict with Oil of Tartar *per deliquium.*

(6) If a little of it be ground in a Glaſs Mortar, with twenty times its own Weight of Nitre, it does not take Flame, but only diſperſe a ſhining Property through the Body of the Nitre; but if ground in the ſame Manner with Iron-Filings, reduced to Powder, a bright Flame immediately enſues.

(7) Though this *Phoſphorus* appears to be a Kind of Sulphur; yet it does not diſſolve in high rectified Spirit of Wine, but communicates ſome ſulphureous Parts thereto: For if this Spirit be poured to Water in the dark, it yields a faint Degree of Light.

(8) The Nature of this *Phoſphorus* is conſiderably changed, by being long digeſted with Alcohol: For thus it becomes a Kind of white tranſparent Oil, that does not coagulate without an extreme Degree of cold, nor afford any Manner of Light; and when freſh Spirit of

Wine is poured thereon, it does not like other Oils, mix therewith, nor diſſolve therein.

(9) If this *Phoſphorus* be ſeparated from the Spirit of Wine wherewith it was digeſted, and be afterwards well waſhed in common Water, it, by Degrees, recovers its former Conſiſtence, and coagulates into a tranſparent Matter, whiter than before; but neither affords ſo much Light, nor recovers its primitive ſhining Virtue, nor its yellow Colour.

(10) The Spirit of Wine ſo ſeparated becomes yellowiſh, and ſmells ſtrong of the *Phoſphorus*; though it ſhines not, except when poured upon Water.

(11) This *Phoſphorus* being mixed with a large Quantity of Pomatum, makes, as well as with Camphire and the Oil of Cloves, a ſhining Unguent, that may be rubbed on the Hands and Face, without Danger of burning, ſo as to render them luminous in the Dark.

(12) If a Piece of Paper, or Linen, be dipt at one End in Spirit of Wine, and a Bit of *Phoſphorus* be cruſhed on the other End that remains dry, the Spirit will be fired by the *Phoſphorus*, without immediate Contact: But the ſame Thing will not happen, if the Paper were dipt in Oil of Turpentine, nor if a Bit of *Phoſphorus* were rubbed upon the End dipt in the Spirit of Wine; only when the Spirit is entirely evaporated the *Phoſphorus* will burn, though with Difficulty, and ſlowly.

44. There are many of theſe odd Kind of Experiments that might be made with *Phoſphorus*; which is a Subſtance that ſeems, in Chemiſtry, to be much ſuch a Thing as the Loadſtone in Natural Philoſophy; and its effects are almoſt as odd and difficult to explain, for want of knowing the latent Properties of Bodies.

AXIOMS *and* CANONS.

1. We learn from the preceding Experiments, That Gunpowder, and the Arts thereon depending, are capable of farther Improvement; and that more forcible and deſtructive Inventions, than thoſe at preſent in Uſe, are diſcoverable, if required *a)*.

2. That, in particular, great Uſe may be made of compreſſed Air in this Way, the Mixture of Iron-Filings and Brimſtone, in large quantities; the *Pulvis* and *Aurum fulminans*; Salt of Tartar; the Mixture of certain cheap Oils and acid Spirits, for producing extremely powerful and deſtructive Effects *b)*.

3. That many natural Phænomena, ſuch as Earthquakes, Thunder, Lightning, Vulcanos, the *Aurora Borealis*, Hot Baths, *&c.* are imitable and explicable by chemical Experiments, particular Mixtures, and exploſive Powers *c)*.

4. That Fire and Flame are producible by the ſimple Mixture of appropriated Bodies, if made with ſufficient Violence: or that Oils freed of their acid Part, and ſuddenly joined with ſtrong acid Spirits, are inſtantaneouſly productive of Fire and Flame *d)*.

5. That by this Action, or the intimate and ſtrong Union of acid Spirits with Oils, Roſins are producible *d)*.

6. That very violent Fxploſions may be made *in vacuo*, as well as in the open Air *d)*.

7. That the *Phoſphorus* of Urine is applicable to many extraordinary Purpoſes; particularly to the introducing of uncommon Changes in metalline Bodies *e)*.

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a) See *Exp.* I. II. and V. *b) Exp.* I. II. III. V. *c) Exp.* III. IV. V. VI. *d) Exp.* V. *e) Exp.* VI.

8. That as moſt Diſcoveries of chemical Exploſions and *Phoſphori* were accidental, greater Things may be expected from a ſagacious Experience, conducted by Reaſon, and by a farther Diſcovery of Cauſes and Axioms *a*).

9. That the *Phoſphorus* of Urine may be made in large Quantities, and with ſmall Expence; ſo as to afford deſirable Opportunities for the farther Improvement of Chemiſtry and Metallurgy *b*).

10. That there may be many latent Properties in Bodies, remaining unknown to us, for Want of making the proper Experiments; which alone can diſcover, and bring thoſe Properties to light *a*).

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a) See *Exp.* I. II. III IV. V. VI.
b) *Exp.* VI.

LECTURE XX.

CONTAINING

Ways of applying Chemiſtry *to the farther Service and Improvement of* Natural Philoſophy, Arts, Trades, *and* Buſineſs.

I.

Deſign. 1. OUR preſent Lecture is intended to ſhew ſome particular Ways of extending and applying Chemiſtry to the farther Improvement of Natural Philoſophy, Arts, Trades, and Manufactures. For though this be the general Deſign of our whole Courſe, yet we judge it proper to beſtow our laſt Lecture expreſsly upon the Subject. We ſhall therefore (1) divide Chemiſtry into its ſeveral Branches, and ſhew how each of them may be farther improved; (2) exhibit a ſet of Experiments tending to that End; and (3) offer a few Rules for its farther Applition and Enlargement.

Chemiſtry divided, 2. *Chemiſtry*, in general, may be uſefully divided into Philoſophical, Technical, Commercial, and Oeconomical Chemiſtry.

Into Philoſophical, 3. By *Philoſophical Chemiſtry* we underſtand Chemiſtry practiſed in Miniature, after the Manner of our preſent Courſe; ſo as to find out the Cauſes of phyſical Effects, and to make new Diſcoveries in Nature*.

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* See below § 7.

4. By *Technical Chemiſtry* we underſtand the Application of Philoſophical Chemiſtry to the immediate Service of ſome Art; ſo as to invent, form, aſſiſt, promote, or perfect it in the large Way of Buſineſs. *Technical,*

5 By *Commercial Chemiſtry* we mean the Application both of Philoſophical and Technical Chemiſtry to the eſtabliſhing, ſupporting, and improving any Branch of Trade or Commerce. *Commercial,*

6. And by *Oeconomical Chemiſtry* we mean the Application of Philoſophical, Technical, and Commercial Chemiſtry to the Service and Accommodation of a Family. *And Oeconomical.*

7. Philoſophical Chemiſtry conſiſts of three Parts; *viz. Invention*, *Rationale*, and *Experiment*: Whence we may define it a particular Exerciſe of the rational and inventive Faculties of the Mind, leading to Experiments, and thence to the Diſcovery of Cauſes; ſo as to form Axioms, that ſhall rationally Account for Phænomena, and diſcover Rules of Practice for producing uſeful Effects. And thus Philoſophical Chemiſtry is not only a Key to all the other Parts, but of itſelf diſcovers the Cauſes of many natural Phænomena; as particularly Earthquakes, Vulcanos, Vegetation, the growth of Minerals *&c.* *Philoſophical Chemiſtry; its Parts:*

8. This Branch of Chemiſtry alſo explains the general Forms and Qualities of Bodies, whereon their Properties and Effects depend; as Volatility and Fixedneſs, Fluidity and Firmneſs, Colours, Taſtes, Odours, Effervefcences, Fermentation, Solution, Precipitation, Congelation, Extraction, and the like. *Its Office.*

9. To this Part of Chemiſtry it likewiſe belongs to bring new Inventions to the Teſt, ſo as to diſcover their Validity or Inſufficiency. Thus when any Hint is ſtarted for a new Trade, or

Method invented for the Improvement of an old one, before any Attempt is made to apply it in the larger Way, the proper Aſſay or Experiment muſt firſt be performed in Miniature; where if it prove ſucceſsful, this may rationally encourage the erecting of ſuch a Diſcovery into an Art, or its Application to the Improvement of Buſineſs.

Illuſtrated. 10. To have an Example of this whole Procedure, we need but reflect upon the general Office of the Aſſay-Maſter; who before-hand diſcovers, in Miniature, the Quantity of Metal contained in any Ore aſſigned; thereby giving a Direction to the Operator at the larger Furnace. And thus Philoſophical Chemiſtry plays directly into the Hands of the Technical, Commercial, and Oeconomical Species.

Its Improvement, by a portable Laboratory. 11. But before it can do this to the beſt Advantage, there are ſeveral Deficiencies therein that require to be ſupplied: And firſt, the Labour, Time, and Expence neceſſary to procure the proper Furnaces, Veſſels, Utenſils, and Subjects, for the ready and commodious Exerciſe of this Art, have been a great Hindrance to its Advancement. Upon which Conſideration we have endeavoured to collect together a commodious *Philoſophical Laboratory* in a portable Form attended with as many Conveniencies as the Nature of the Thing will allow *a)*.

By practiſing it, without Fire or Furnace. 12. In our Definition of Chemiſtry *b*), we endeavoured to avoid the common Error of confining this Art to the ſole Uſe and Application of Fire. We hope to have ſhewn *c*) that it has a Right to employ the other Elements, Air, Water, and Earth; to which we may add Cold,

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a) See the Eſſay for introducing a Portable Laboratory.

b) *Lect.* I. *in init.*

c) *Lect.* I. II, III, IV,

and various Kinds of Motion. And if it be remembered, that Chemiſtry is the Art of analyſing and compounding Bodies by Means of all the Inſtruments we can procure; an Attempt to introduce Ways of working in the Art, without Fire or Furnace, will not appear ſurprizing.

Particularly by means of Cold.

13. Nay, if a due Eſtimate were made, and the full Scope and Extent of Chemiſtry conſidered; a large and curious Part of it would appear to depend more upon other Things, than upon the direct Uſe of Fire: Thus for Example, the whole of Fermentation and Putrefaction, two Extenſive Operations in Nature and Art, are performable without the Uſe of either Fire or Furnace. Farther, the Action or inſtrumental Efficacy of Air, Water, and Earth might, with regard to chemical Operations, be oppoſed to the Action of Fire; which has ſtill a more direct Antagoniſt, or rather Correlative, *viz.* Cold; whoſe Efficacy in Chemiſtry is extremely great, and ſeparates the more uſeleſs and aqueous Parts of Bodies from thoſe that are more ſpirituous and eſſential; as we ſee in the Concentration of Wines, Vinegars, and other ſpirituous and ſaline Liquors by Froſt *.

Chemiſtry improveable by collecting the Experiments and Practices of Artiſts.

14. There is farther wanting to the Improvement of *Philoſophical Chemiſtry*, a Collection of all that is hitherto known and practiſed in the Art, to ſhew the preſent State and Condition thereof. And this, perhaps, would make no very large Volume; for the original Experimental Writers are very few, in Compariſon of the Collectors and Tranſcribers: But the more uſeful Part of ſuch a Work is not to be found in Books; and can be had only from obſerving, collecting,

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* See the laſt of three Eſſays in Artificial Philoſophy, or Univerſal Chemiſtry, *Ann.* 1731.

and digeſting the daily Practices of mechanical Operators; ſuch as Refiners, Aſſay-Maſters, Smelters, Dyers, Sugar-Bakers, Soap-boylers, &c. And till the Secrets and Myſteries of theſe Arts are known to the chemical Philoſopher, he will want many things that are neceſſarily required to the Improvement of Philoſophical Chemiſtry.

A Liſt of Deſiderata.

15. The laſt particular we ſhall at preſent intimate, as wanting for the Exerciſe and Improvement of Philoſophical Chemiſtry, is a Liſt of the Chemical *Deſiderata* in all Arts and Trades, in order to procure the readieſt Ways of ſupplying them: For ſuch a Liſt would contain ſo many Problems for the Philoſophical Chemiſt to ſolve.

Technical Chemiſtry divided.

16. We now proceed to *Technical Chemiſtry*; which, for the Sake of Uſe and Commodiouſneſs, we divide into four Parts: as it relates to Subjects of the animal, vegetable, and mineral Kingdoms; or to ſeveral of them at once. Thus under animal Arts comes the Art of preparing Size and Glue, Tanning, Ivory-Staining, the Dying in Wool, Silk, &c. Under vegetable Arts comes the Art of Timber, or the Ways of preſerving it ſound againſt the Injuries of the Weather, the Sea, &c. the Art of making Roſin, Pitch, Oil of Turpentine, Charcoal, Pot-Aſh, &c. the Art of Brewing, and Fermenting for Wines, Vinegars, &c. the Art of Sugar-making, and Refining; the Art of Soap-making, &c. Under mineral Arts come the Arts of Salt, Copperas, Vitriol, Borax, Pottery, Metals, Foundery, Smithery, &c. And laſtly, under mixed Arts comes the Art of Paper, the Art of Ink, the Art of Japanning, the Art of Glaſs, the Art of Pigments, the Art of Pharmacy, the Art of Fire-Works, &c. all which are

proper chemical Arts, that fall under Technical Chemiſtry.

17. It were eaſy to give a Catalogue of a large Number of new, and probably advantageous, Arts or Trades, that might be ſet up in *England*. Thus, for inſtance, we would recommend the Introduction of *Engliſh* Arracks and Brandies; which might be plentifully afforded by the Tappings of our Trees, and all Kinds of Summer-Fruits: Nor need Wines themſelves, even from the Grape, be here excepted; eſpecially as we have an excellent Method of improving all poor and thin Wines, by adding fine flavourleſs Sugar in the Fermentation *.

How to be improved.

18. We have endeavoured to ſhew, in the preceding Lectures, that many of our Trades are improveable; particularly Brewing, Diſtilling, Soap-boiling, Pharmacy, Metallurgy, *&c.* And for new Trades, that the refining and making of various Commodities may be as advantageouſly practiſed in *England* as elſewhere: And among theſe may be reckoned the refining of Borax, Camphire, Tartar, Manna, *&c.* the making of Salt-Petre, the obtaining of Sulphur, the making of blue Vitriol, Porcellane, artificial Gems, and numerous other Commodities of Price and Uſe.

19. The great thing wanting to the Advancement of Arts, and the Perfection of this whole Affair, ſeems to be the joint Concurrence of certain Perſons, who ſhould contribute to the carrying it on. The Compaſs of Knowledge allotted to a ſingle Man or two, bears no Proportion to that required for the due conducting of this Work: Nor, perhaps, is the Knowledge in being, of the Kind here principally required.

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* See *Lect.* XI.

Arts and Sciences muſt receive their Improvements chiefly from *Phyſical Knowledge*; that is, a Knowledge drawn from the Nature of Things, which is to be acquired only by converſing with natural Bodies, and obſerving their Properties, by putting Bodies together, and ſeparating them again. And this general Proceſs is to be conducted in the way of a *ſagacious Experience*; which is a Matter of Judgment, not caſual or accidental, but formed upon ſome certain Principles and Analogy of Knowledge. Thus we ſee, in ordinary Life, and the Practice of Trades, that Men educated to them have an acquired Sagacity, or Habit of judging each in his own way; which Sagacity is rarely to be found in Men differently educated. The Qualifications therefore required for our preſent purpoſe may be termed, *Phyſical or Chemical Habits of judging about Things relating to Arts and Trades*, acquired by ſome competent Experience, or by being for ſome Time verſed in this Way.

20. If Choice were made of a Set of Men ſo qualified, and Rules given them to purſue, with due Care to regiſter all their Experiments, and form them into *Tables*, from whence ſome ſhould derive Canons and Axioms, others deduce the more uſeful Things for the Service of Arts and Trades, *&c.* So as to make an uniform and ſteady Buſineſs of the whole; there is good Reaſon to expect that, in the compaſs of a few Years, conſiderable Improvements might be made in the preſent ſet of Arts and Sciences.

Commercial Chemiſtry divided.

21. *Commercial Chemiſtry* conſiſts of three parts, *viz.* (1) The Exerciſe of all the Chemical Arts, in a large Manner; ſo as to ſupply more than the Demands of a ſingle Country, and afford a Surplus of Commodities for Exportation and foreign Conſumption; (2) The various Ways of

condenſing, curing, preparing, ſecuring, and fitting natural and artificial Commodities for Carriage and Tranſportation ; And (3) the Ways of ſupplying the chemical Neceſſaries to Voyagers and Travellers, for founding, ſupporting, and improving Trade, Traffic, and Commerce, in different Countries.

How to be improved.

22. And thus a Knowledge of *Commercial Chemiſtry* will eaſily direct us in *England*, to the Arts that may be extended and improved, ſo as to underſell ſome other Nations at the foreign Markets ; provided the Duties and Drawbacks are in our Favour : For example ; We conceive, that Malt-Spirit may be produced in *England* cheaper and better than in *Holland* ; that Wines, Vinegars, Brandies, and Arracks, may be made, either here, or in our Plantations, as good as, and perhaps cheaper than, in their preſent places of growth and Importation ; that White Lead, Verdigreaſe, Sal-Amoniac, Pot-Aſh, Hard Soap, *&c.* may be prepared as cheap and good in *England* as in any other Part of *Europe*.

23. We are likewiſe inſtructed by *Commercial Chemiſtry*, to reduce Goods to their leaſt Volume or Bulk for Exportation ; and again to ſecure them from the Injuries of the Sea, the Weather, and other Accidents. Thus Metals come to be exported inſtead of their Ores, Sugars inſtead of the Juice or Rob of the Sugar-Cane, Salt inſtead of Sea-Water, Raiſins inſtead of Grapes, high Spirits inſtead of low Wines, Pot-Aſh inſtead of refuſe Wood, *&c.* And thus it is that, by means of Technical and Commercial Chemiſtry together, different Countries are ſupplied with Lead, Tin, Iron, Silver, Oil, Tallow, tanned Hydes, Pitch, Roſin, Brimſtone, Wax, Wines, Brandies, Salt, Sugars, Treacle, Paper, *&c.* whereby all

Trade, Traffic, and Commerce, is ſupported. And to diſcover this Kind of Contrivance, or Reduction, is the Office of Commercial Chemiſtry. Thus, inſtead of importing many Tuns of a foreign dying Wood, we are taught to extract its tinging Parts, and bring them away in the Quantity of a few Pounds. And to do this more generally, as it may be done, would tend to perfect the Trade of the Dry-Salter, and leſſen the Expence of the Dyer.

24. Another Advantage of *Commercial Chemiſtry* is, that it affords the Neceſſaries for long trading Voyages. Thus, in particular, it directs us to a *Chemical Cheſt*, and a *Portable Furnace*, with its Apparatus of Flux-Powders, for aſſaying Ores; a Screw-Preſs for Oils, and a Still for examining fermented vegetable Juices. It alſo directs us to the certain Rules of diſcovering the Sophiſtications practiſed in Wines, Brandies, Vinegars, Arracks, Gold-Sand, Gold in Bars or Ingots, counterfeit Gems, *&c.* and to the ways of aſſaying Pot-Aſh, Tincal, Amber-greaſe, Muſk, and all other Drugs. So that to improve this Part of Chemiſtry, little more ſeems required than the bringing it into more general Uſe; which might be done to great Advantage, if Philoſophical and Technical Chemiſtry were firſt improved to any conſiderable Degree.

Oeconomical Chemiſtry divided.

25. We now come to our laſt Diviſion of Chemiſtry, *viz.* the *Oeconomical* Branch; which is of great Utility and Extent, ſo as to be capable of improving all the reſt. This Branch we chooſe to divide with regard to the ſeveral Offices of a Houſe, in which, as in ſo many different Laboratories, it may be commodiouſly practiſed: For Inſtance, in the Brewhouſe, the Store-Room, the Kitchen, the Dairy, the Laundry, and the Cellar. Thus, by Means of

Oeconomical Chemiſtry, we are inſtructed in the beſt Ways of brewing with Malt, Treacle, Hony, Sugar, or other vegetable Juices; the beſt Ways of raiſing and preſerving Yeaſt, or Wine Lees, for baking or brewing; and of imitating the natural Wines of foreign Growth. This Art directs us how to procure the ſimple and compound Waters of Vegetables, in their greateſt Perfection; and to make a Set of Brandies or Cordial Waters, even from the groſs Lees, Sediments, or Bottoms of our Wine or Ale Caſks. Hence alſo we learn the Methods of preſerving Fruits in Sugar, and ſeveral vegetable Productions in the Way of Pickle, *&c.* The Art of Cookery alſo is by this Means improveable: So are all the Dairy Productions, and the Buſineſs of the Laundry; as by rendering hard Waters ſoft, *&c.* But to ſhew this fully, and to improve the Deſign, would require a particular Treatiſe, under the ſeveral Heads of the *Brewhouſe*, the *Store-Room*, the *Kitchen*, the *Dairy*, the *Laundry*, and the *Cellar* *.

II.

Purport of the Experiments.

26. We now proceed to our Experiments; the *firſt* whereof will ſhew that Sal-Ammoniac may probably be made to as great Advantage in *England* as in the *Levant*; the *ſecond* will ſhew the Method of making a Varniſh of Amber, with a View to improve the Arts of Japanning, Embalming, *&c.* the *third* will ſhew how to make a very hard Glaſs, for improving the Art of Glaſs, Enamelling, and the Buſineſs of artificial Gems; the *fourth* will ſhew how to prepare a Foil for foliating figured Glaſſes, and

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* See the firſt of the three Eſſays in *Artificial Philoſophy*, or *Univerſal Chemiſtry*, publiſhed in 1731.

turning them into Speculums; the *fifth* will ſhew a Way of making a curious and uſeful Glue; and the *ſixth* and laſt will ſhew a Method of giving Copper a Gold Colour, and a greater Degree of Ductility, by Way of directing an Enquiry after Methods of introducing other uſeful Changes into Metals.

EXPERIMENT I.

That Sal-Ammoniac may be advantageouſly made in England.

Sal Ammoniac prepared.

27. We took four Ounces of the common volatile Salt of Ox-Bone, and ſaturating it with ſtrong Spirit of Sea-Salt, evaporated the ſuperfluous Moiſture; upon which we found a Cake of true Sal-Ammoniac left behind.

Uſe of the Experiment.

28. This Experiment regards both Philoſophical and Technical Chemiſtry; as not only ſhewing that Odours may depend upon the Mechanical Structure or Texture of the Parts of Bodies; but alſo leading to a cheap Way of obtaining Sal-Ammoniac in other Countries, as well as in the *Levant*.

In Philoſophical Chemiſtry, or the Doctrine of Odours.

29. The volatile Salt here employed has a very quick and pungent Odour; ſo likewiſe, though in a leſs Degree, has the Spirit of Salt: but theſe two, upon mixing, deſtroy each other's Odour, ſo as to leave the Cake of Sal-Ammoniac ſcentleſs. The Reaſon is, that theſe two odorous Liquors loſe of their Volatility by Mixture; ſo that their fine Parts can no longer fly off briſkly, and ſtrike the Nerves of the Noſe, on which all ſmelling depends. But if a little of the Sal-Ammoniac be ground in a Mortar, along with another ſcentleſs, but more fixed, Body, *viz.* an equal Quantity of Salt of Tartar; this

Salt of Tartar laying hold of the Acid of the Sea-Salt, leaves the volatile Salt at Liberty to aſcend and ſtrike the Noſtrils as briſkly as before: Whence we ſee that Odours may be mechanically produced and deſtroyed. The ſame is confirmed by many other Inſtances of Philoſophical Chemiſtry, and holds equally of Taſtes.

Rules for improving Perfumes.

30. Hence we may derive ſome Rules for improving the Odours of certain Perfumes, or for recovering them when impaired, or almoſt deſtroyed. Thus it is known to Perfumers, that Sugar being ground with Muſk or Ambergreaſe, opens the Body thereof, and makes theſe Subſtances go farther in the perfuming of Waters, Powders, or the like: And this the Sugar does chiefly, by attenuating, reſolving, and ſubtilizing the viſcous Parts of thoſe Sweets, ſo that they now move more freely, and ſtrike the Noſtrils more briſkly, than before. And when theſe, or other Perfumes, have almoſt loſt their natural Odour, it may in good Meaſure be recovered by the prudent Addition of a little volatile, animal Salt; as that of Hartſhorn. And hence we ſee the phyſical Reaſon why decayed Perfumes are ſometimes ſuſpended in a Jakes, to recover their loſt Odour; for all ſuch Places abound with volatile Salts, continually ariſing from the Urine, and other animal and vegetable Matters, which are there in a State of Putrefaction.

Sal-Ammoniac obtainable.

31. Sal-Ammoniac is alſo obtainable in *England*, by ſubliming a Mixture of Wood-Soot, Urine, and Sea-Salt; but it ſeems eaſier and perhaps it might prove cheaper, to prepare it in the Way of the preſent Experiment. The volatile Salt for the Purpoſe will be abundantly ſupplied by the Pith of Horns, Blood, the Refuſe

of a Slaughter-houſe, putrified Vegetables, &c. and the Spirit of Salt may be made at an eaſy Rate, in a proper Furnace.

The Experiment extended. 32. But the preſent Experiment might prove ſtill more ſerviceable, by leading to a Way of procuring other ſaline Bodies beſides Sal-Ammoniac: For it ſhould ſeem that ſeveral Salts may be artificially compoſed by the Union of their conſtituent Parts; as we here ſee in Sal-Ammoniac. For Example; the Making of blue Vitriol may be attempted, by boiling Copper, inſtead of Iron, in the raw Liquor of the Pyrites, from which the common green Vitriol is made. And if this Hint were duly purſued, perhaps it might lead to the Diſcovery of ſeveral new Arts and Trades.

EXPERIMENT II.

An Amber Varniſh.

Amber diſſolved. 33. We took four Ounces of Amber, and putting it into a Crucible, juſt melted it with a ſmall Degree of Heat; then poured the fluid Maſs upon the Iron Plate. When the melted Matter grew cold, we reduced it to Powder; and adding thereto two Ounces of drying Oil, (that is, Linſeed Oil prepared, or thickened, by boiling it with a little Litharge) and one Pint of Oil of Turpentine, we diſſolved the whole together into a Varniſh.

Uſe of the Experiment. 34. This Method of making the Amber Varniſh is kept as a Secret in few Hands; but deſerves to be made publick, as a leading Experiment, to direct the Means of perfecting the Arts of Varniſhing and Japanning, or the Ways of diſſolving Amber; whereon the Perfection of various Arts may depend. Thus, in particular, the Art of Embalming would be highly improved, if we could preſerve the human Corps in a tranſparent Caſe of Amber; as we ſee the Bodies of Flies, Spiders, Graſhoppers, *&c.* are, to great Perfection.

Approximation. 35. An uſeful Subſtitute, or Approximation, in this Way, has been tried, by boiling fine Roſin to Colophony, or a tranſparent and hard, though brittle, Subſtance. This being diſſolved by Heat, and the Bodies of ſome ſmall Animals dipped therein ſeveral times ſucceſſively, they have been thus coated over with Colophony; which in ſome Degree reſembles Amber, but requires to be carefully kept from Duſt, in order to preſerve its Tranſparency.

Uſes of diſſolving Amber. 36. But if Amber could be diſſolved without impairing its Tranſparency; or if one large Maſs could be made of it, by uniting a Number of ſmall ones, it would thus not only tend to perfect the Art of Embalming, but likewiſe come to be uſed, on many Occaſions, inſtead of Wood, Marble, Glaſs, Silver, Gold, and other Metals: for then various Kinds of Veſſels and Utenſils might be commodiouſly made thereof.

How to attempt its Solution. 37. To forward the Diſcovery, our preſent Experiment ſhews, that Amber contains a certain ſlimy, aqueous, or mucilaginous Part, which in the ordinary Way requires to be evaporated by a ſcorching Heat, before the Amber will readily diſſolve in Oil; with which however it afterwards unites into a Subſtance of a Nature compounded of that of an Oil, a Gum, and a Roſin. Nor would the thin ethereal Oil of Turpentine diſſolve it, unleſs firſt thickened, and fitted for this Purpoſe, by Means of the drying Oil. Hence, as it ſeems plainly intimated that Amber is not only reſinous, but alſo mucilaginous, whoever would attempt to melt ſmall Pieces of Amber into large ones, would do well to conſider the Subject as a mucilaginous Roſin, and conſequently (1) fitted to diſſolve, in a thick Oil, after a previous Evaporation of its aqueous Parts, or the Deſtruction of its more mucilaginous Nature; (2) that it may poſſibly be diſſolved, by boiling in a Lixivium of Salt of Tartar, and Quicklime; or if any could be found, as there may, ſtill ſharper, and more alkaline; and (3) that the Digeſtor ſeems well adapted to diſſolve this mucilaginous and reſinous Subſtance, by Means of an expreſſed Oil added to the Amber, finely powdered and kept from ſcorching by the Interpoſition of Water. And here we recommend a long and moderate Digeſtion, rather than a violent Heat. Thus, therefore, our preſent Experiment points out to us three Methods for diſſolving Amber, which either do not conſiderably deſtroy its Texture, or at worſt leave it in a State reducible, by an eaſy Operation, to a Kind of Amber again.

EXPERIMENT III.

A harder Glaſs than the common.

Borax Glaſs. 38. We took four Ounces of Borax, and an Ounce of fine white Sand, reduced to Powder, and melted them together in a large cloſe Crucible, ſet in a Wind Furnace, keeping a ſtrong Fire for half an Hour; then taking out the Crucible, and breaking it when cold, we found at the Bottom a pure hard Glaſs, capable of cutting common Glaſs almoſt as well as a Diamond.

Uſe of the Experiment. 39. We have here an Experiment, which, being duly varied, may lead to ſome conſiderable Improvements in the Arts of Glaſs, Enamels, and artificial Gems: It ſhews us an expeditious

Method of making Glaſs, without the Uſe of a fixed Salt; which has generally been thought an eſſential Ingredient in Glaſs, and which is the Ingredient that gives the common Glaſs its Softneſs. But Borax is a neutral Salt, which, being urged by the Fire, does not turn any Way alkaline; but, of itſelf, without Addition, preſently runs into Glaſs. And whether other Ingredients might not here be advantageouſly ſubſtituted for ſoft Sand, particularly calcined Flints, powdered Cryſtal, *&c.* we recommend to farther Experience; ſo as to attempt making a Glaſs that ſhall, in ſome Degree, approach the Hardneſs of a Diamond.

40. If a pure tranſparent Glaſs, of this Degree of Hardneſs, can be tinged in the ordinary Manner, by Means of the prepared metalline Calces, it ſhould ſeem that the Art of making counterfeit Gems would then have gained its Perfection; for the Colours thus introduced are in no reſpect inferior, but perhaps ſuperior, to the natural Colours of the Sapphire, Emerald, Ruby, *&c.* So that nothing more ſeems wanting to perfect this Art, than the Diſcovery of a denſe, hard, cryſtalline Glaſs, that ſhall poliſh like Cryſtal, and not ſcratch in the Wear.

The Experiment extended.

41. In order to give our Glaſs the deſired Degree of Hardneſs, it may be proper to continue it long in the Fire; which is conſtantly found to add Strength and Hardneſs to Glaſs: Inſomuch that common Glaſs, by being conſtantly kept in a ſtrong Fuſion for a Month or ſix Weeks, has become of a ſtony Hardneſs; a large Part of the fixed Salt thus going off in the Fire; and conſequently leaving the Glaſs leſs charged with Salt, or nearer approaching to the native Hardneſs of the Flint or Sand employed in the Preparation.

42. If the Uſe of Borax ſhould, in this Manner, be found to have a conſiderable Effect, it will be proper to enquire farther into its natural and chemical Hiſtory, which ſeems at preſent to be little regarded. Perhaps it may not be impoſſible to find this uſeful Subſtance in ſome Parts of *Europe*, or to imitate it by Art, and to diſcover better Ways of refining it than thoſe now uſually practiſed.

43. The Facility wherewith this Salt runs into Glaſs, or the ſmall Degree of Heat, and the ſhort Time required for that Purpoſe, if well attended to, may be capable of enriching Chemiſtry, and more particularly the Hiſtory of Glaſs; at leaſt we have good Reaſon to believe that the preſent Experiment is capable of being largely diverſified, and improved to the Service of ſeveral Arts.

EXPERIMENT IV.

A Foil for turning ſpherical or other figured Glaſſes into Speculums.

The Silvering Amalgam. 44. We took half an Ounce of clean Lead, and melted it with an equal Weight of pure Tin; then immediately added half an Ounce of Biſmuth, and carefully ſkimmed off the Droſs: Now removing the Ladle from the Fire, we added, before the Mixture grew cold, five Ounces of pure Quickſilver, and ſtirred the whole well together; then put the fluid Amalgam into a clean Glaſs.

How to be applied. 45. When this Amalgam is uſed for Foiling, or Silvering, let it firſt be ſtrained through a linen Rag; then gently pour ſome Ounces thereof into the Glaſs intended to be foiled. The Mixture ſhould be poured into the Glaſs by Means of a paper Funnel, reaching almoſt to the Bottom, to prevent its flying to the Sides; then dexterouſly inclining the Glaſs every Way, endeavour thus to faſten the Foil. When this is once done, let the Glaſs reſt for ſome Hours; then repeat the Operation, till at length the fluid Maſs is evenly ſpread and fixed over the whole internal Surface; as it may be known to be by viewing the Glaſs againſt the Light. The ſuperfluous Amalgam being now poured out, the Outſide of the Glaſs may be poliſhed with Putty, Chalk, or Tripoli, ſprinkled upon a Cloth: And thus the Operation is compleated. In this Manner are made thoſe ſhining ſpherical Glaſſes (appearing like Glaſſes filled with Quickſilver) which we ſometimes ſee hung up in Parlours, near the Cieling, to invite the Flies in Summer from the Windows, and other Parts of the Room, where they might prove more offenſive.

Advantages of the Operation.

46. The Operation has conſiderable Advantages, as being performable in the Cold; and is not attended with Danger from the poiſonous Fumes of Arſenic, or other unwholeſome Matters, uſually employed for this Purpoſe. And how far it is applicable to the more commodious foiling of the common Looking-Glaſſes, and other Speculums, may deſerve to be conſidered.

EXPERIMENT V.

A curious and uſeful Glue.

Iſing-Glaſs Glue.

47. We took an Ounce of Iſing-Glaſs beat to ſhreds, and put it into a Pint of Brandy; where, by Means of a little Heat, or gentle ſimmering over a common Fire, it gradually diſſolved: We then ſtrained the Solution through a Piece of fine Muſlin, and thus obtained a

Glue, that ſhould be kept in a Glaſs cloſe ſtopped.

Its Uſes. 48. This Glue, with a very gentle Heat, diſſolves thin, tranſparent, and almoſt limpid: When uſed in the Manner of common Glue, it joins the Parts of Wood together, ſtronger than Wood is joined to itſelf; ſo that the Pieces thus joined will break in any other Part rather than where they are glued. It is alſo remarkable, that if Saw-duſt, or powdered Wood, be made into a Ball with this Glue, the Ball will prove ſolid and elaſtic; ſo that it may be turned and uſed as a Bowl, without breaking. And whether, by Means of ſuch a Glue as this, ſomething conſiderable may not be effected in the emboſſing of Wood-work, we leave to farther Experience. The Glue being thus made with Brandy, will keep long without corrupting; and is therefore a proper Form wherein to preſerve Iſing-Glaſs ready diſſolved for the fining of Wines, or other Uſes.

Extended. 49. Another curious Uſe of our Glue is, that it ſerves excellently for taking off the Impreſſions of Medals, or Coin: Thus if a little of this melted Glue be poured thinly upon a Guinea, ſuppoſe, ſo as to cover the whole Surface of the Piece, and the Glue be ſuffered to remain thereon for a Day or two, till it becomes thoroughly dry, it will appear hard and tranſparent, like a Piece of *Muſcovy* Glaſs, with the Impreſſion of a fair Guinea in *Entaglio*, as they call it, on one Side, and in *Relievo* on the other.

And improved. 50. This Glue, therefore, dries into a very ſtrong, tough, and tranſparent Subſtance; not eaſily to be hurt or damaged by any Thing but aqueous Moiſture, which would ſoon diſſolve it: So that it is not fit to be uſed in any Work that muſt be expoſed to Wet or Weather. But for a

Glue to ſtand the Weather, let choice be made of the common Glue diſſolved with Linſeed-Oil.

Hiſtory of Glues wanted.

51. The natural and experimental Hiſtory of Glue might greatly tend to the Improvement of Chemiſtry. For it ſhould ſeem as if all animal and vegetable Subſtances were either originally made of, or might at laſt be reſolved into Glue or Jelly. Doubtleſs a Knowledge of the Nature of Ropineſs, Viſcidity, Sizineſs, Mouldineſs, *&c.* would give conſiderable Light to Natural Philoſophy and Medicine, and lead us farther into the Effects, Nature, and Proceſs of Growth, Fermentation, and Putrefaction. This Enquiry, therefore, ſhould be proſecuted with Care; beginning, for Example, with that viſcous Subſtance the White of the Egg, or Serum of the Blood, in their natural States; and obſerving how their Tenacity is altered, by moderate Degrees of Warmth or Cold. The Enquiry might next proceed to the mucilaginous Matter of Snails, Frog-Spawn, Fiſh, and other Animals in Embrio, Vegetables, *&c.* and gradually deſcend to Subjects of the mineral Kingdom. And this Enquiry, we apprehend, may be uſefully proſecuted without the Aſſiſtance of a chemical Apparatus; ſo as to diſcover the beſt Ways of preparing Cements, Glues, Sizes, Jellies, *&c.* for various mechanical and oeconomical Uſes.

EXPERIMENT VI.

Copper made more ductile, and turned of a Gold Colour.

52. Make an Amalgam, of one Part pure Copper, and three Parts clean Quickſilver; boil

Copper advanced ſomewhat nearer to Gold.

boil the Amalgam in River-Water for two Hours; then diſtill off the Quickſilver, and cohobate it once or twice; laſtly, fuſe the Copper that remains in the Retort, and it will be of a Gold Colour, and more ductile than common Copper. This Experiment was not brought to Perfection in the Courſe, on Account of the Difficulty then found of amalgamating the Copper, which was attempted thus: We diſſolved as much Copper in *Aqua fortis* as the Menſtruum would take up; then diluting the Solution with ten or twelve Times its own Weight of Water, we put Iron Plates into it, which precipitated the Copper in fine Powder: This Powder was edulcorated, or waſhed, in ſeveral Waters, to clear it of its adhering Salts, and afterwards dried; then ground in a Stone-Mortar, along with an equal Weight of Quickſilver; but no Amalgamation enſued. It has been uſually thought difficult, and by ſome impracticable, to make an Amalgam of Copper by Heat: In which Method, indeed, it is not eaſy to ſucceed perfectly, the Copper requiring ſuch a Heat to keep it fluid, as will exhale the Mercury; which beſides does not readily unite with that Metal. In the preſent Method the Thing may be effected without Heat; *viz.* by firſt reducing the Copper to an exceeding fine Powder; which here ſupplies the Place of Fuſion, and might put us upon enquiring whether Trituration may not, in ſome other Caſes, be advantageouſly ſubſtituted for Fuſion.

Its Uſe.

53. This uncommon Experiment of M. *Homberg* ſhews us a Method of advancing Copper ſome Degrees nearer to Gold; ſo as to fit it for Watch-work, Cane-heads, Snuff-boxes, and other ſmaller Machines and Utenſils, and eſpecially for Gilding. It is remarkable that the

Quickſilver loſes an eight Part of its Weight in the Operation.

54. The Experiment is here employed as a leading one, capable of ſhewing that uſeful Changes may be wrought upon the common Metals; ſo as, in ſome Meaſure, to introduce a new Set. It is known to ſome, that Copper may be ſo far whitened and ſoftened, as to ſerve on many Occaſions for Silver. Lead, by a ſlight Application, is capable of being whitened, hardened, and rendered more uſeful for many Purpoſes. And if Perſons acquainted with the Nature and Effects of Metals, Minerals, and their Fumes upon each other, were to proſecute the Enquiry, many uſeful Things of the like Kind might doubtleſs be diſcovered. *Extended.*

55. A little prepared or fixed Arſenic will inſtantly whiten Copper throughout; though thus indeed the Copper proves brittle, or rotten: But there are other ſecret Ways of whitening it, ſo as to leave it extreamly ductile. *Exemplified.*

56. The farther Proſecution of this Subject would lead us into the ſublimer Metallurgy; which is a Part of Chemiſtry by no Means hitherto cultivated as it deſerves, ſeeing it is highly capable of enriching the known mechanical Arts, and ſtriking out new ones. *The Proſecution recommended.*

III.

57. We now come to offer a few *Rules* for conducting chemical Experiments in the Way of an Art; ſo as to improve the ſeveral Branches of Chemiſtry above mentioned *. *Rules for improving Chemiſtry and Arts.*

58. Let the firſt Rule be, with Care and Diligence to obſerve the Proceſſes uſed by Nàture in

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* § 2, &c.

the Production of all thoſe things we would endeavour to imitate. For Nature, the moſt expert Chemiſt, employs the very Inſtruments which Men alſo employ; *viz* Fire, Water, Air, and Earth; as we have ſhewn in our Lectures upon the Elements.

Illuſtration. 59. To illuſtrate this Rule by an Example; it appears, by numerous Inſtances, that there is an acid or ſaline Liquor naturally contained in the Bowels of the Earth; which acid there mixing with various Kinds of earthy Matters, and acting as a Menſtruum upon them, changes their Natures, or makes them appear under different Forms. And hence common Brimſtone, Alum, the native Vitriol, *&c.* ſeem to have their Origin.

60. For by an exact Scrutiny and attentive Conſideration it appears that, when this general Acid diſſolves a certain bituminous Earth, it makes Brimſtone; when a chalky Earth, Alum; when Iron or Copper, Vitriol; *&c.* And accordingly, by uſing the ſame Kind of general Acid (which may be procured by burning Brimſtone under a glaſs Bell) in the ſame Manner as Nature ſeems to employ it, we can likewiſe, by Art, produce Brimſtone, Alum, or Vitriol, when and where we pleaſe. And thus, if we could univerſally diſcover the Proceſſes and Inſtruments which Nature employs in the Production of her Effects, we ſhould have certain Rules for imitating her.

Rule II. 61. Our ſecond Rule is, to gain a Habit of transferring, diverſifying, enlarging, and improving an Experiment, till it ends in ſome certain Diſcovery, either of Light to the Underſtanding, or of Uſe in Life; one of which points all juſt Experiments will end in, when duly proſecuted and conſidered.

62. For unſucceſsful Experiments are no leſs inſtructing than thoſe that ſucceed: Which ought to be well remarked. The Head muſt in all Caſes co-operate with the Hands: So that the Mind ſhould be ever caſting about to diſcover the Cauſes of Failure, as well as of Succeſs. And this is a Sagacity which may be procured by Uſe, and turned into a Habit of Invention and Diſcovery: So that no ſingle Experiment ſhall be performed, but ſome Advantage will be immediately derived from it; nor any Experiment be made, without ſome reaſonable Grounds of Hope for Succeſs. *Illuſtration.*

63. Our third Rule is, To proſecute Experiments in an orderly Series, with a View to ſome particular Enquiry that may be of Uſe in Life; and to let the Enquiry ſuit the Genius and Temper of the Enquirer, ſo as that it may be proſecuted by him with Vigour and Pleaſure. *Rule* III.

64. Thus, if any one ſhould be averſe to the Uſe of Fire and Furnace, he may ſtill improve Chemiſtry and Arts, or perform many ſerviceable chemical Operations, without much Apparatus, or Expence, or without the Utenſils and Inſtruments commonly employed in that Art: Which may, therefore, be practiſed as well in a Study or Parlour, as in a Laboratory. And to thoſe diſpoſed to operate in this Way, may be recommended the Buſineſs of Fermentation, the Concentration of Liquors by Cold, and the Proſecution of the Nature and Hiſtory of Cold, begun by Mr. *Boyle*. We might alſo recommend the extracting of the finer Eſſences of Vegetables; the making of the more noble and ſpirituous Infuſions, Tinctures, and Elixirs; the examining and tabling the ſolutive Power of Water with regard to Salts, and of Spirit of Wine with regard *Illuſtration.*

regard to different Oils and Roſins; the determining the Force of all known Menſtruums in the Cold; the Diſcovery of new Menſtruums, and particularly of a Solvent for the Stone. Theſe, and many other chemical Enquiries, may be proſecuted without the Uſe of Fires and Furnaces: And even ſuch Tempers as are more delighted with Speculation than Practice, may greatly contribute to the Improvement of Chemiſtry, by ſorting, ranging, and digeſting Experiments into Tables; ſhewing what they prove, and how far they reach; how far they fall ſhort, and how they may be carried farther: Others might employ themſelves to Advantage, in drawing Things of Uſe from the Experiments already known and publiſhed: And laſtly, others might, from a due Conſideration of Experiments, deduce new Directions and Rules of Practice for producing, in a ſure and conſtant Manner, much greater Effects than are uſually hoped for.

AXIOMS *and* CANONS.

1. We learn from the preſent Lecture, that Chemiſtry is an Art of very extenſive Uſe in Life; inſomuch that not only Natural Philoſophy, but alſo Trades, Commerce, and all active Buſineſſes, have a Dependence upon it, and may be improved by it *.

2. That therefore the Diſeſteem, which Chemiſtry has generally met with, proceeds from a Want of knowing its proper Office, Extent, and Uſefulneſs; and from the frequent Miſapplica-

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* See the whole Lecture *paſſim*.

tion of it to Things of a deluſory or phantaſtical Nature.

3. That a large Part of general Chemiſtry may be advantageouſly practiſed, and many Diſcoveries and Improvements made therein, for the Service of Arts, without the direct Uſe of Chemical Fires, Furnaces, and the common *Apparatus* *a*).

4. That numerous Diſcoveries and Improvements remain to be made in Chemiſtry itſelf; and that theſe Improvements may be made in a direct, rational Manner; and, if once made, might greatly enlarge and illuſtrate Natural Philoſophy, improve various Arts, and introduce a Set of new ones *b*).

5. That, in particular, Sal-Ammoniac, an Amber-Varniſh, a hard Kind of Glaſs, a Foil for Glaſſes, an excellent Glue, and a new Kind of Metal, may be eaſily obtained, for the Improvement of Pharmacy and Dying, Japanning and Embalming, the Art of Glaſs and the making of artificial Gems, the Foiling of Glaſſes, the Gluing of Timber, Emboſſing, and taking off Impreſſions, the Art of Watch-making, and for other mechanical Uſes.

6. That the Canons for the farther Improvement of Chemiſtry, and the Arts thereon depending, require, (1) a careful Obſervation of the Ways of working employed by Nature; (2) a Talent of Experimenting; and (3) the Diſcretion of ſuiting the Enquiry to the Temper and Genius of the Enquirer *c*).

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a) See § 12, 13. and *Exp.* II. IV. V. and § 63, 64.
b) See the whole Lecture.
c) See § 58——64.

CONCLUSION.

WE are now come to the End of our Lectures, where it may be proper to ſtop a while, and look back upon the Ground we have gone over. We ſeem to ourſelves to have been travelling in a new Road, too little frequented either by Philoſophers, Chemiſts, or Men of Buſineſs. Our Aim has been to improve the uſeful Arts, by Means of a more Philoſophical Chemiſtry; and at the ſame Time to ſhew the Method of conducting Enquiries ſo as that they may terminate in uſeful Diſcoveries. With an Eye fixed upon this Point, we have purpoſely avoided the more entertaining and agreeable Experiments, wherewith Chemiſtry abounds; and have kept to ſuch only as were judged either beneficial in themſelves, or of Service in diſcovering Cauſes, Axioms, and Rules. And if there be any Merit in what we have done, we freely own it to be borrowed, and that it lies in the *Verulamian* Method we have purſued, that is, in endeavouring to rectify the Mind, guard it againſt Error and Illuſion, and conduct it to the Fountains of Nature and Uſe. We cannot indeed preſume to have diſcovered many of the true Cauſes of Things, or Axioms perfectly juſt and univerſal. To do this, requires that the ſeveral Parts of Philoſophy ſhould be better cultivated than they are. All we can hope for is, to have found and eſtabliſhed a few Rules that may direct to a ſerviceable Practice, and enable us to enrich and improve ſome of the preſent Arts and Sciences. Thus, for Example, we hope to have diſcovered this philoſophical Axiom, That *Sugar, or a ſaccharine Subſtance, is the Baſis of Wines, Beers, Vinegars, and inflammable*

mable Spirits : Whence we preſume, that the Arts of Brewing, Wine-making, Vinegar-making, and Diſtilling, may receive a great Degree of Perfection. And thus we deſire to have it obſerved, that the Diſcovery of a ſingle Axiom, or Cauſe, may often improve, or even perfect, a Number of Arts : For phyſical Axioms, duly diſcovered, muſt be pregnant with the Matter of many Arts and Sciences. And on this Account it is, that we have directed our Enquiries to the Inveſtigation thereof, as the beſt and ſureſt Means of improving the known Arts, and diſcovering new ones. Doubtleſs, if this Method were carefully and generally purſued, the Buſineſs of Invention would not long continue to be that caſual Thing it now is ; but be reduced to an Art, which, of all others, is, perhaps, the moſt wanted.

The END.

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